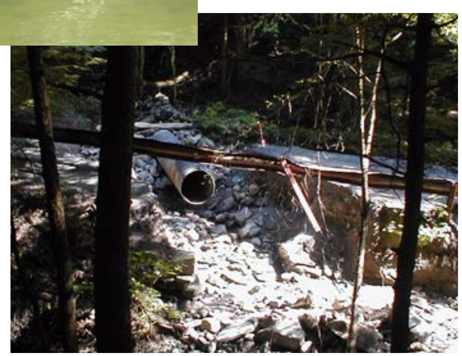
Water from the Hills:

Adapting to land use and climate change

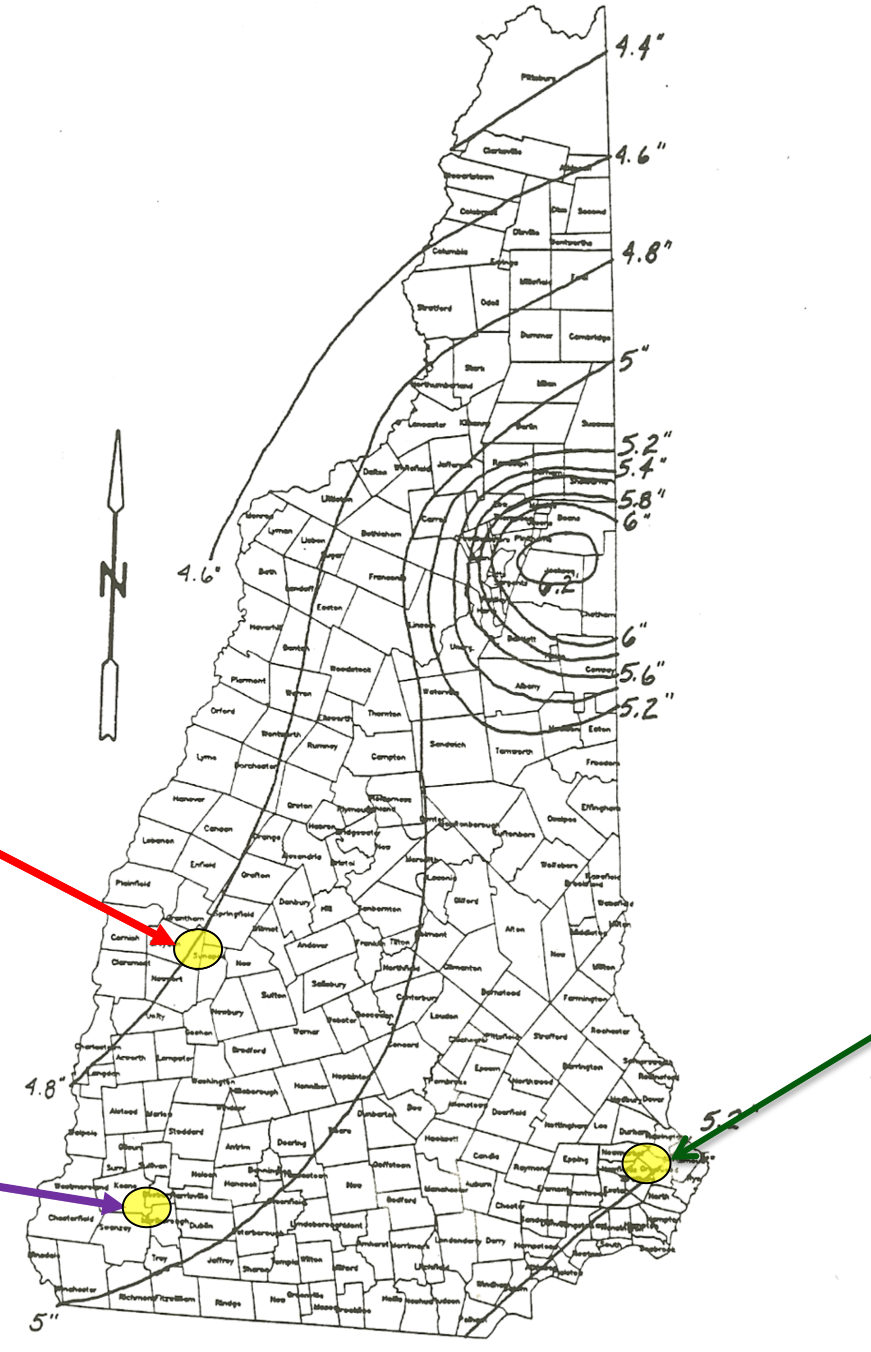


Michael Simpson
Antioch University New England

Research Team
James Gruber, Antioch University New England
Robert Roseen, UNH Stormwater Center Latham
Stack, Syntectic, LLC
Thomas Crosslin, Climate Techniques, LLC
Robert Wood, Lake Sunapee Protective Association
Joel Smith, Stratus Consulting
Colin Lawson, Antioch University New England

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

ANTIOCH UNIVERSITY
NEW ENGLAND

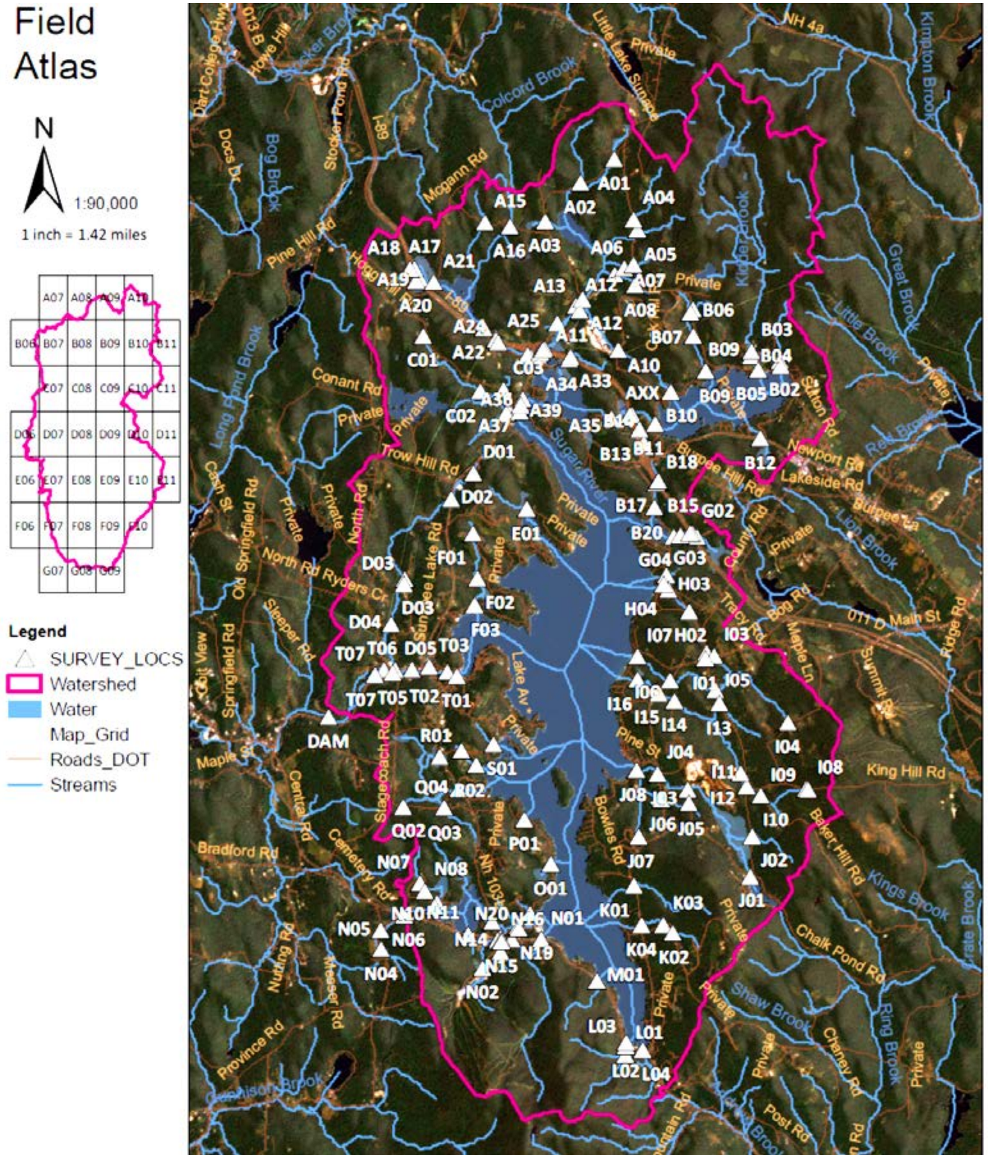


6-9 -- 25-YEAR FREQUENCY 24-HOUR DURATION RAINFALL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

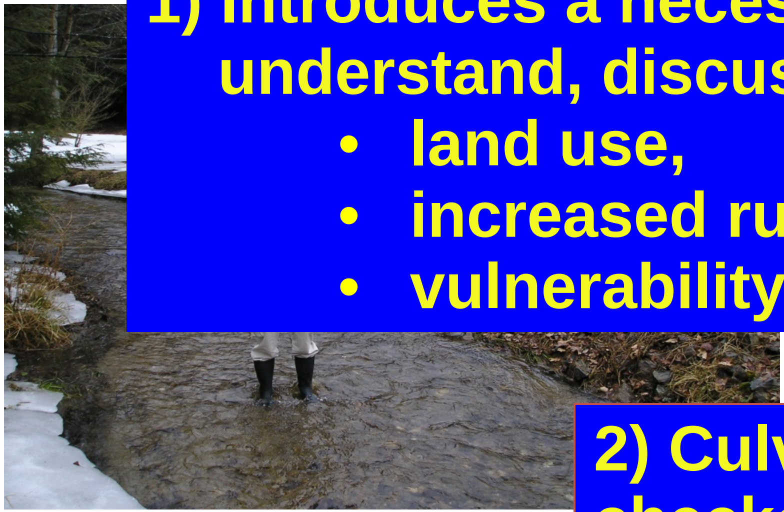
Field Data Collection

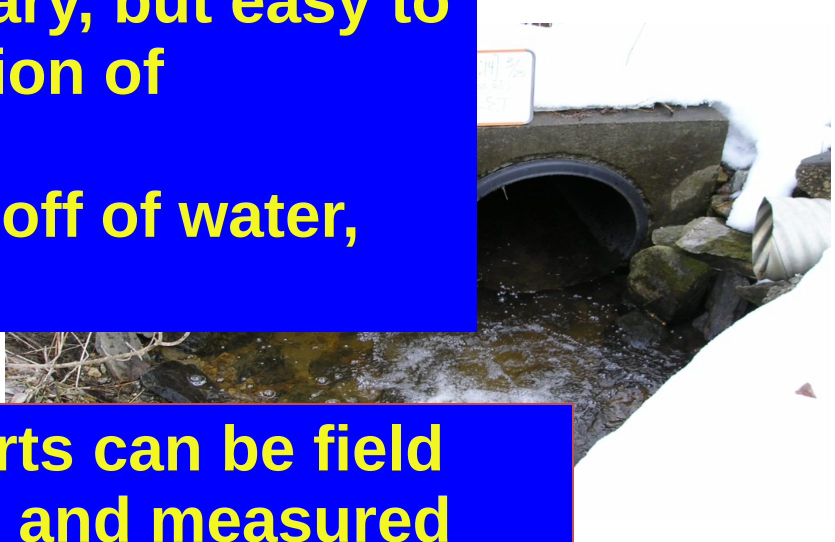
210 road crossings



WHY CULVERTS?

ulvert and landscape characteristics





1) Introduces a necessary, but easy to understand, discussion of
- land use,
- increased run-off of water,
- vulnerability

2) Culverts can be field checked and measured relatively easily

3) Culverts have a tangible dollar value attached to them that can be used in replacement and mitigation cost analyses

DATA Input

Historical Climatic Data
Precipitation
Evapotranspiration

Precipitation Scenarios
Global Circulation Models
Down-Scaling

Current Land Characteristics
Soils,
Water Bodies
Parks /Protected Land

Projected Land Characteristics
Impervious Surfaces
Green Infrastructure

Historic Pipe Configuration

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SYNTECTIC INTERNATIONAL

Modeling

Run-off / Peak Flow Calculations

EPA-SWMM
Calibration

Outputs

Projected Precipitation Amounts
Optimistic - Pessimistic

System Components Adequacy
Current
Projected

Projected Pipe Sizing

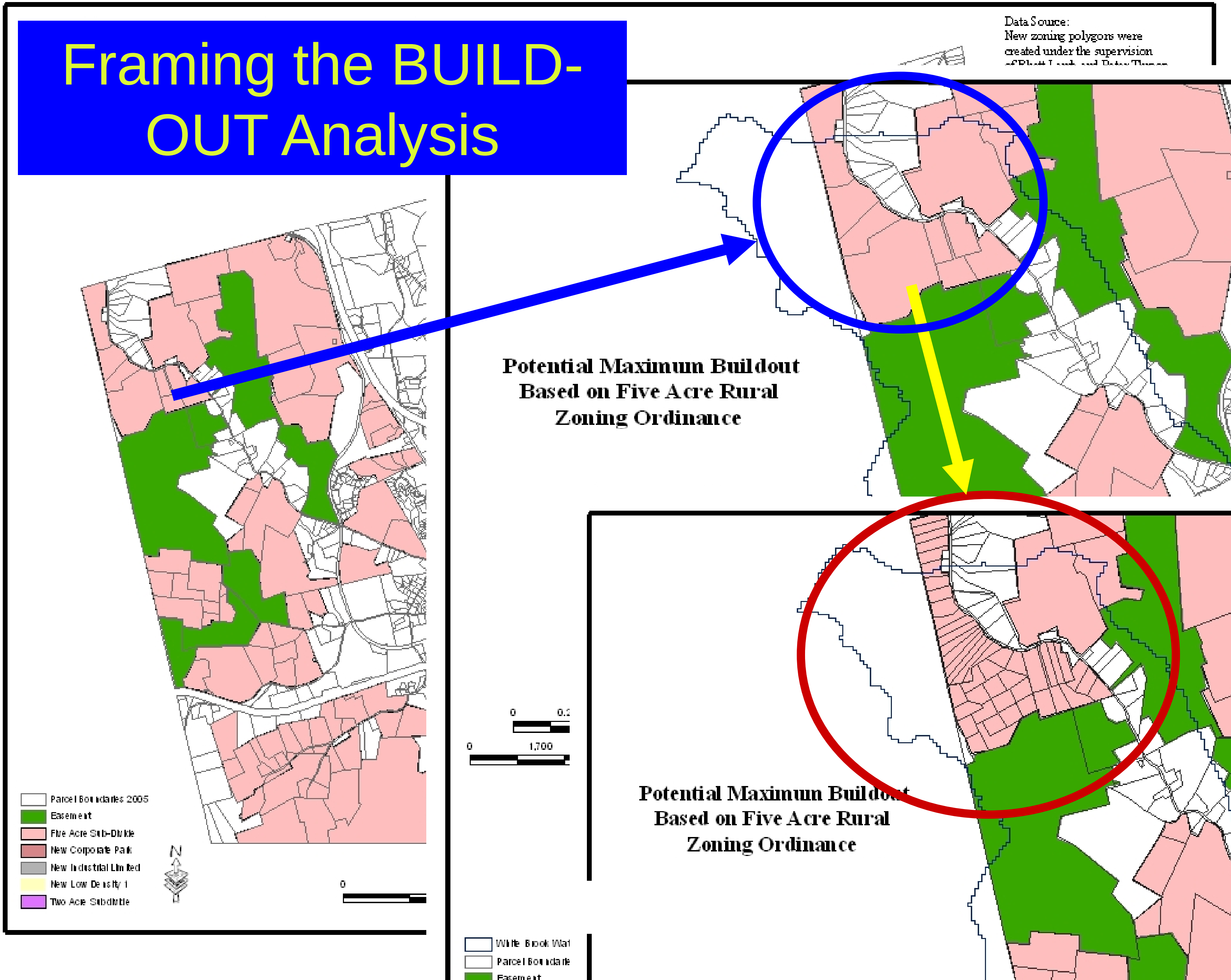
Impact of Green Infrastructure
Extent of Mitigation

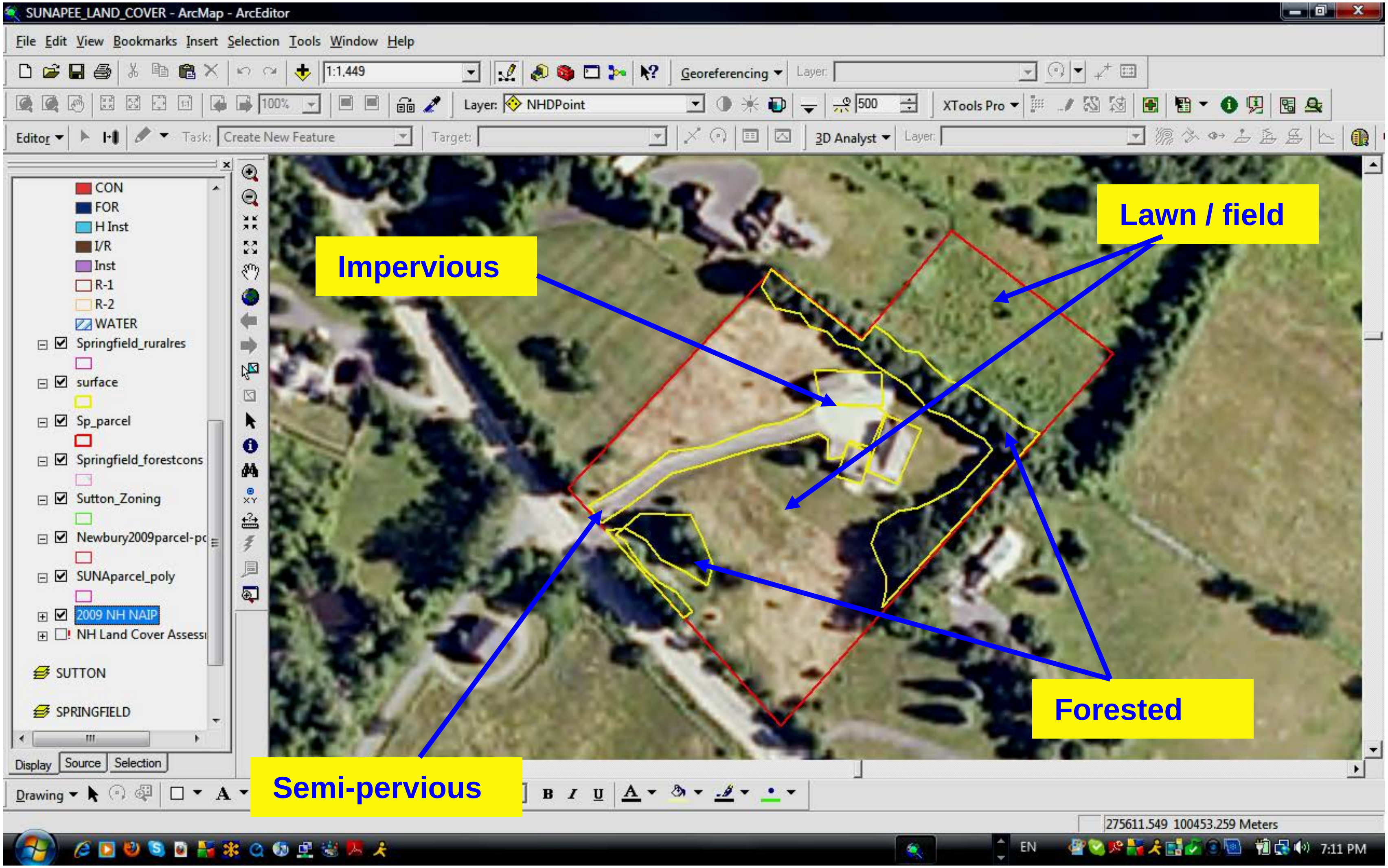
Projected Cost Impacts

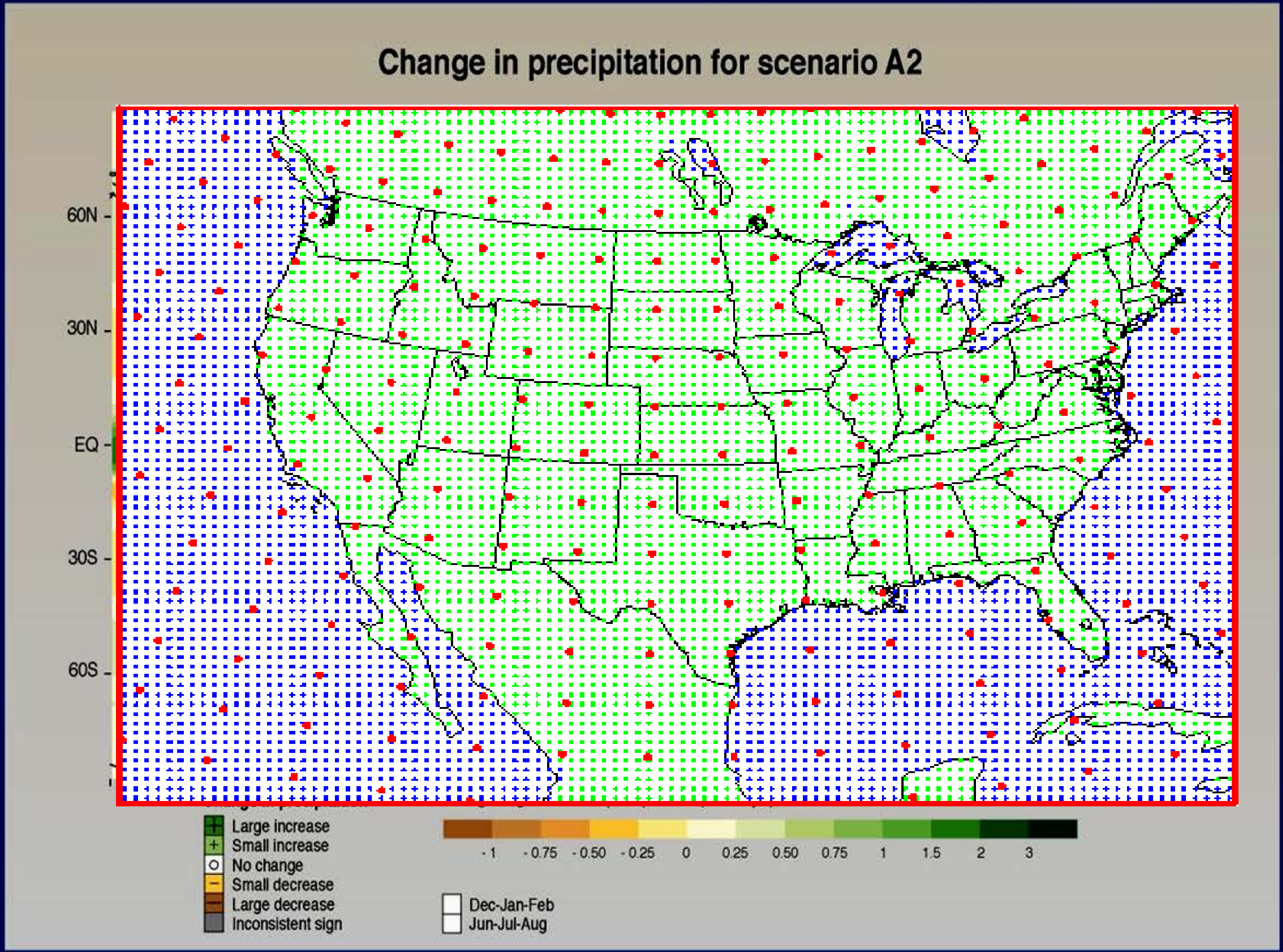
A Changing Landscape

Courtesy of UCONN Cooperative Extension

Framing the BUILD-OUT Analysis



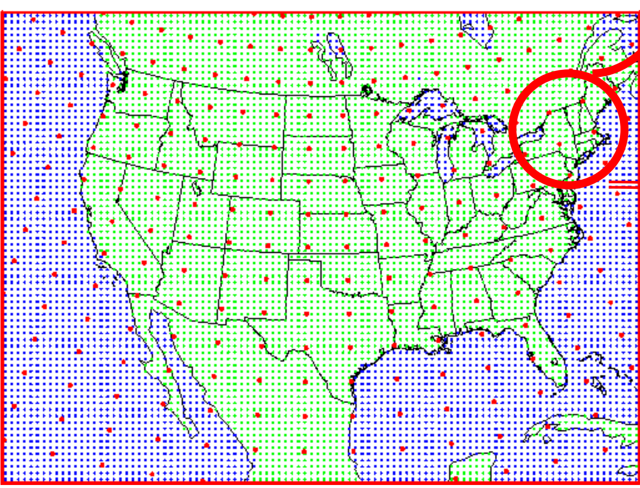

SUNAPEE_LAND_COVER - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
Georeferencing
Layer: NHDPoint
XTools Pro
Editor
Task: Create New Feature
Target:
3D Analyst
CON
FOR
H Inst
I/R
Inst
R-1
R-2
WATER
Springfield_ruralres
surface
Sp_parcel
Springfield_forestcons
Sutton_Zoning
Newbury2009parcel-pc
SUNAparcel_poly
2009 NH NAIP
NH Land Cover Assessi
SUTTON
SPRINGFIELD
Display
Source
Selection
Drawing
Impervious
Lawn / field
Forested
Semi-pervious
275611.549 100453.259 Meters
7:11 PM

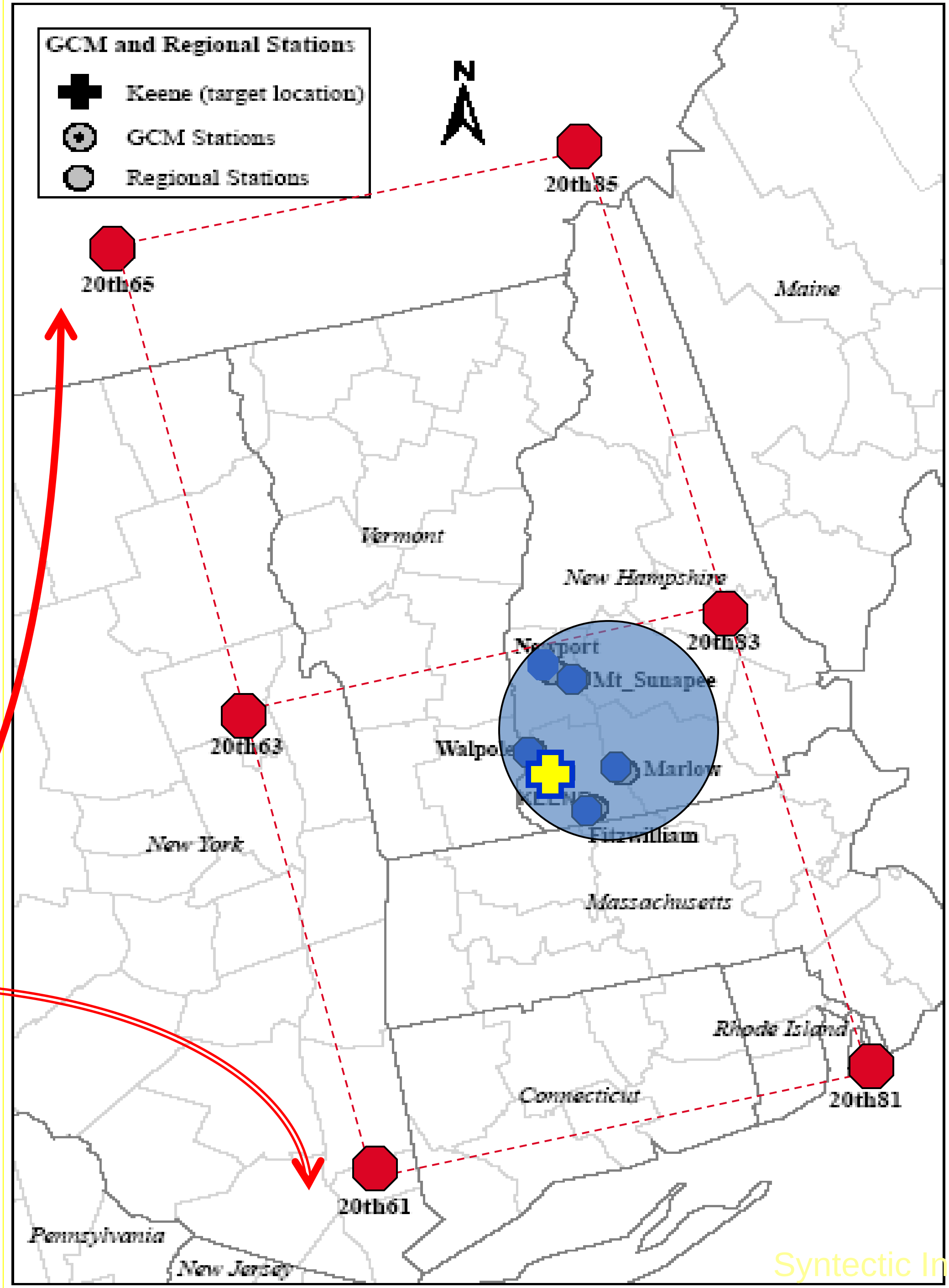


SYR - FIGURE 3-3 a)

A Changing Climate

Six gridpoints proximate to study areas in NH were used to transfer the expected change in precipitation from the GCM to Keene and regional stations





Syntectic Int'l, 04/07

Lake Sunapee watershed:

Results of precipitation modeling

Sunapee 25-year, 24-hour precipitation, regionalized shape parameter

Data Source	SRES	Period	25-year precip (in.) -95%c.i.	Most Likely	+95%c.i.
Historic	Baseline	1971-2000	2.70	4.06	6.65
PROJECTED Rainfalls	B1	2046-2075	2.63	4.25	7.47
	A1b	2046-2075	3.23	4.87	8.00
	A1fi	2046-2075	4.34	6.65	11.10

Most likely potential rainfalls used for determining culvert vulnerability

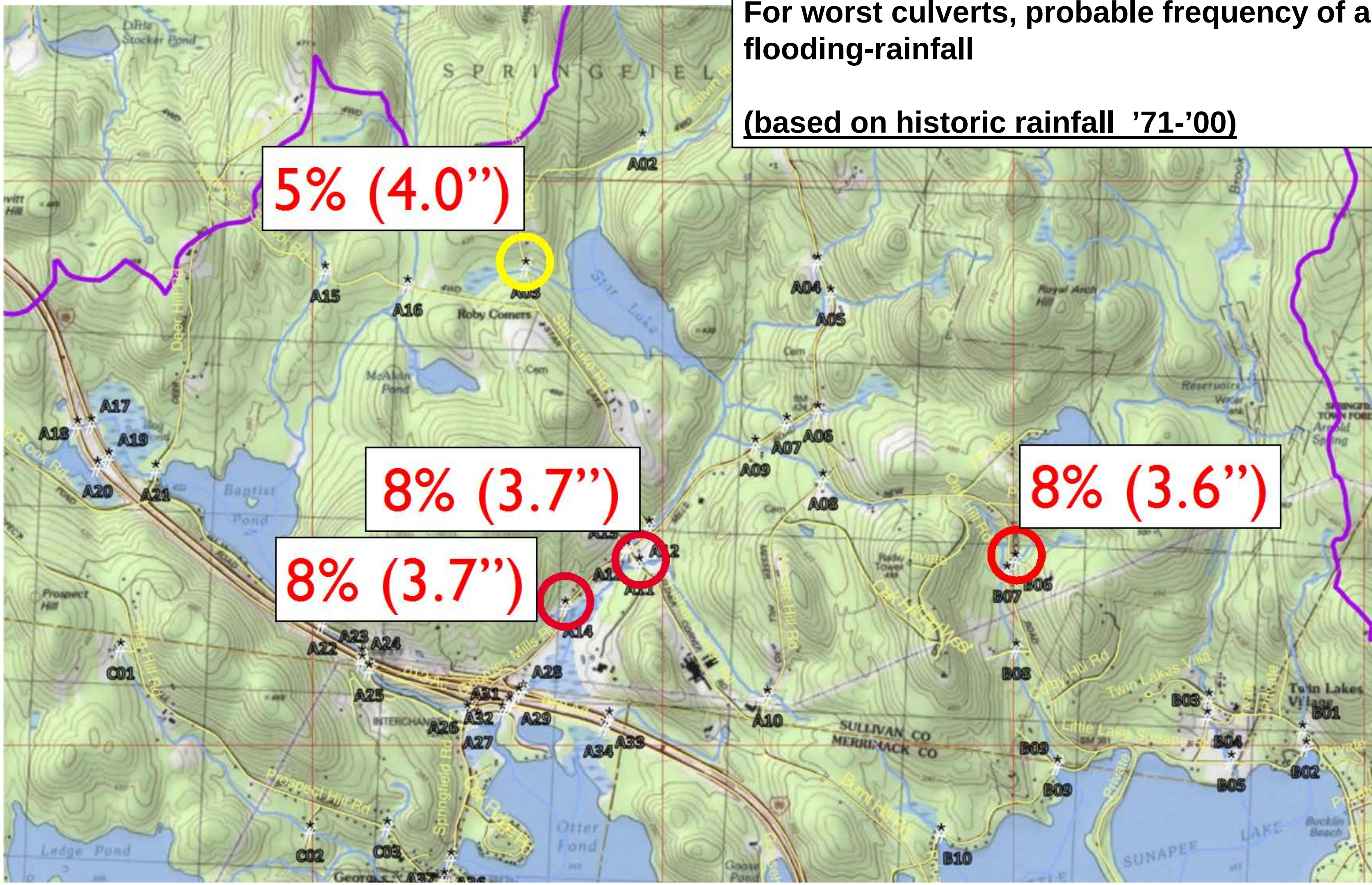
Ranged: 4.06 to 6.65 inches

RESULTS

Springfield drainage system vulnerability

For worst culverts, probable frequency of a flooding-rainfall

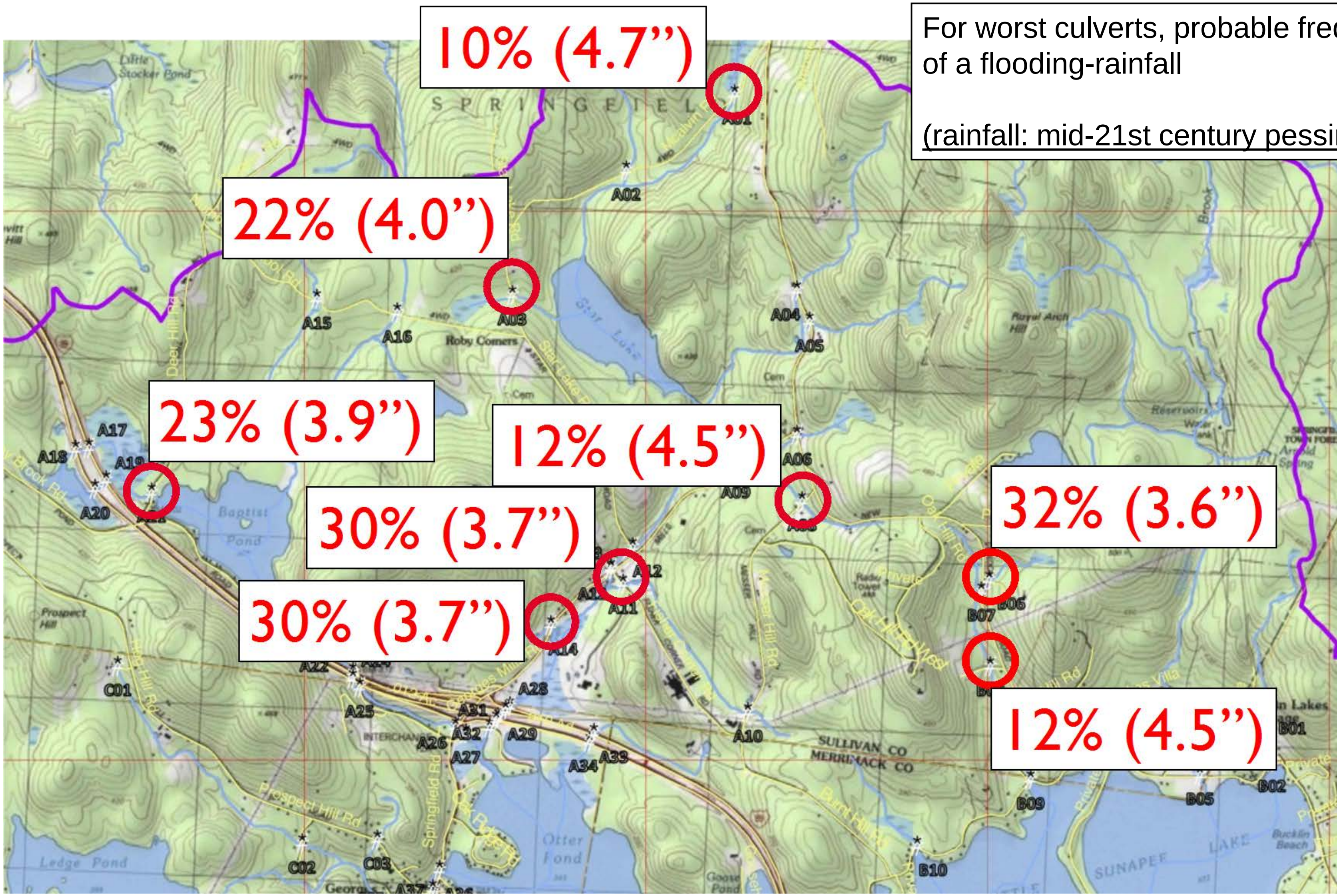
(based on historic rainfall ’71-’00)



Springfield drainage system vulnerability

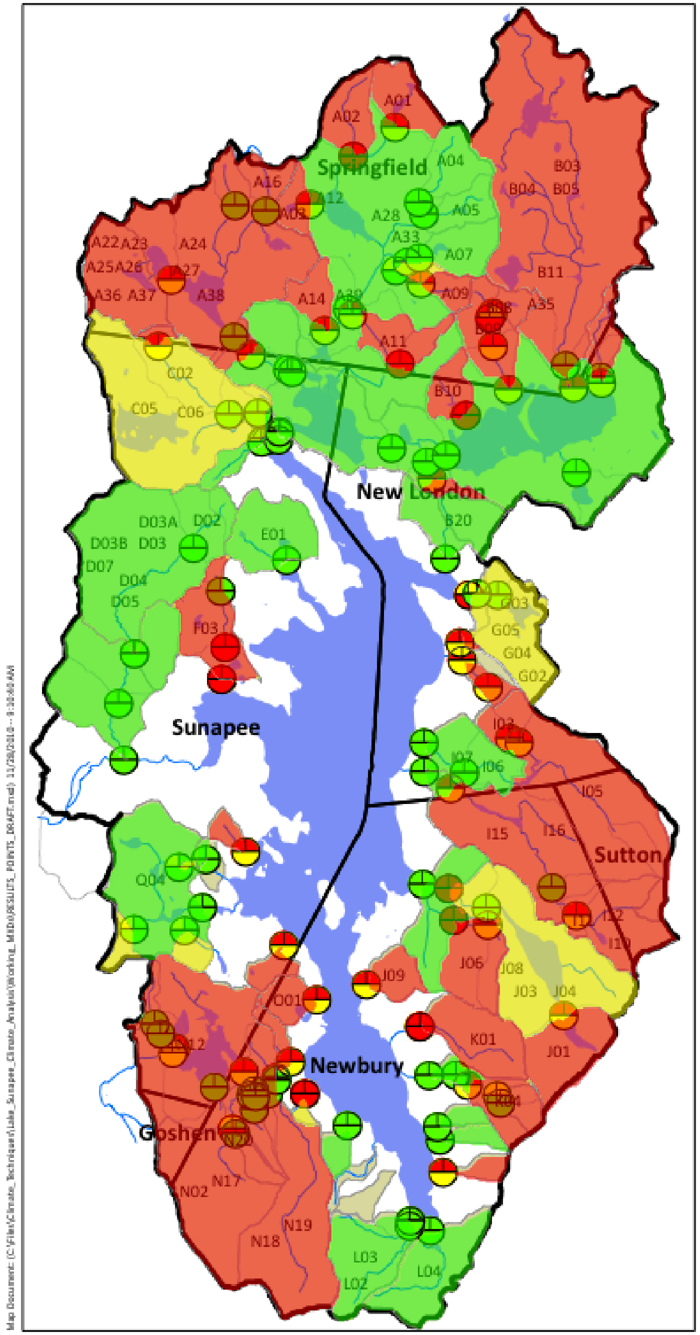
For worst culverts, probable frequency of a flooding-rainfall

(rainfall: mid-21st century pessimistic)

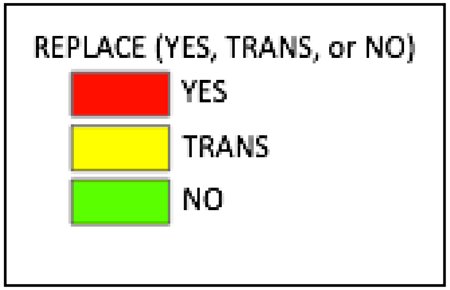


Lake Sunapee watershed:

Spatial impact of undersized culverts

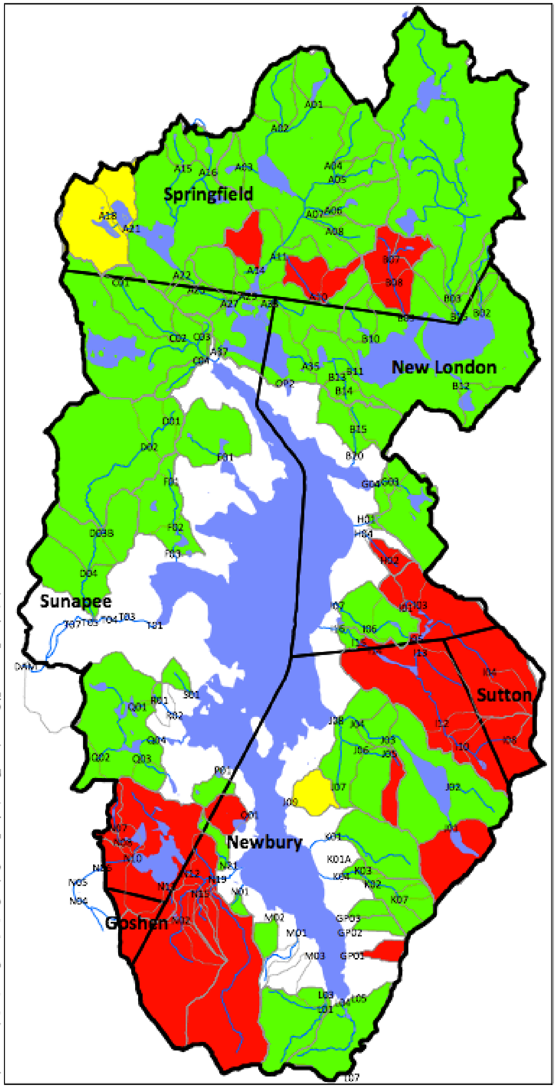


Mid-21st projected 25-yr storm: 35% of culverts undersized



Drainage system adequacy

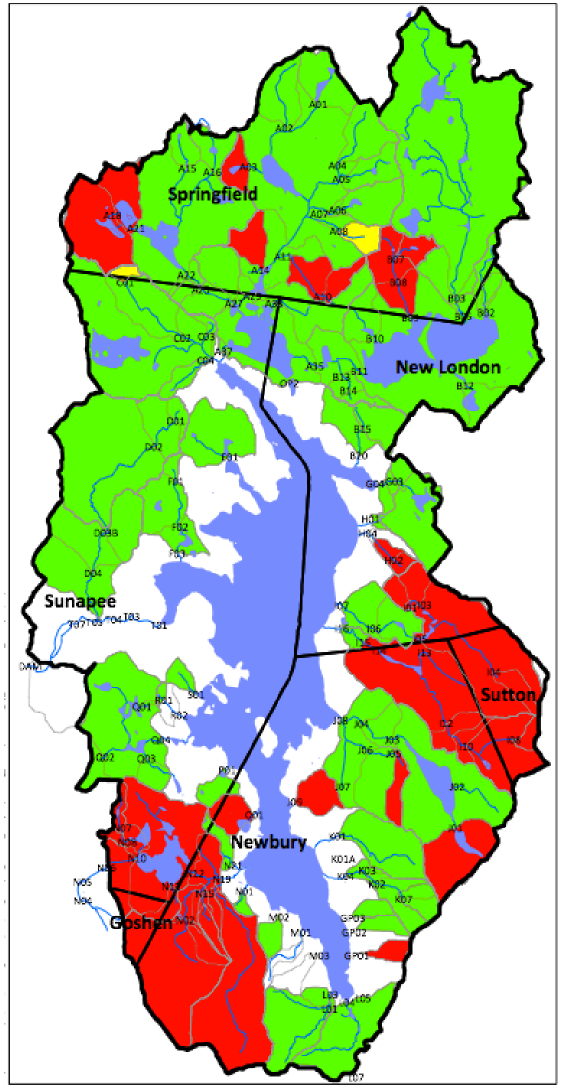
Recent conditions



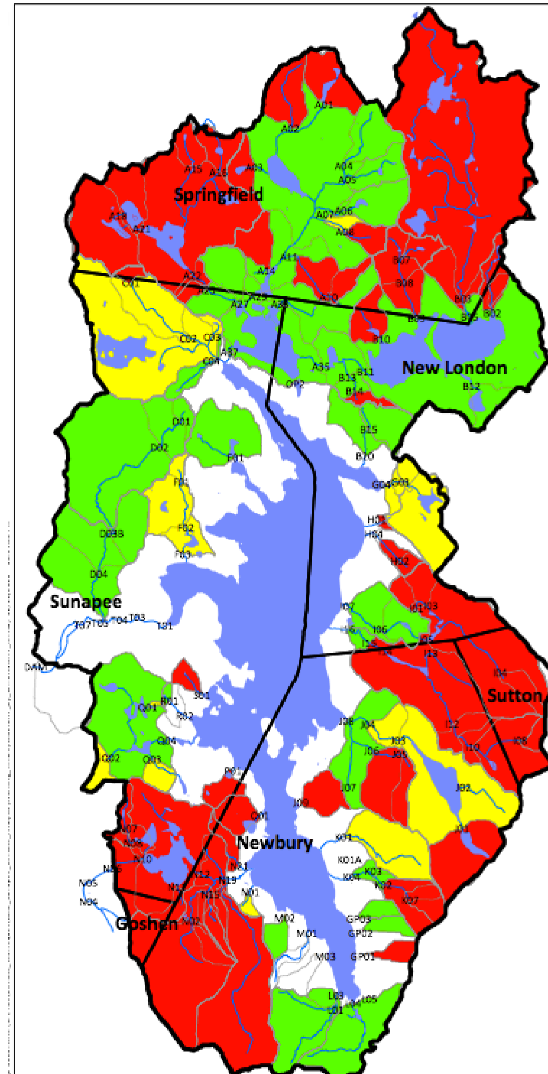
REPLACE (YES, TRANS, or NO)
- YES
- TRANS
- NO

Trans = transitional

With population growth



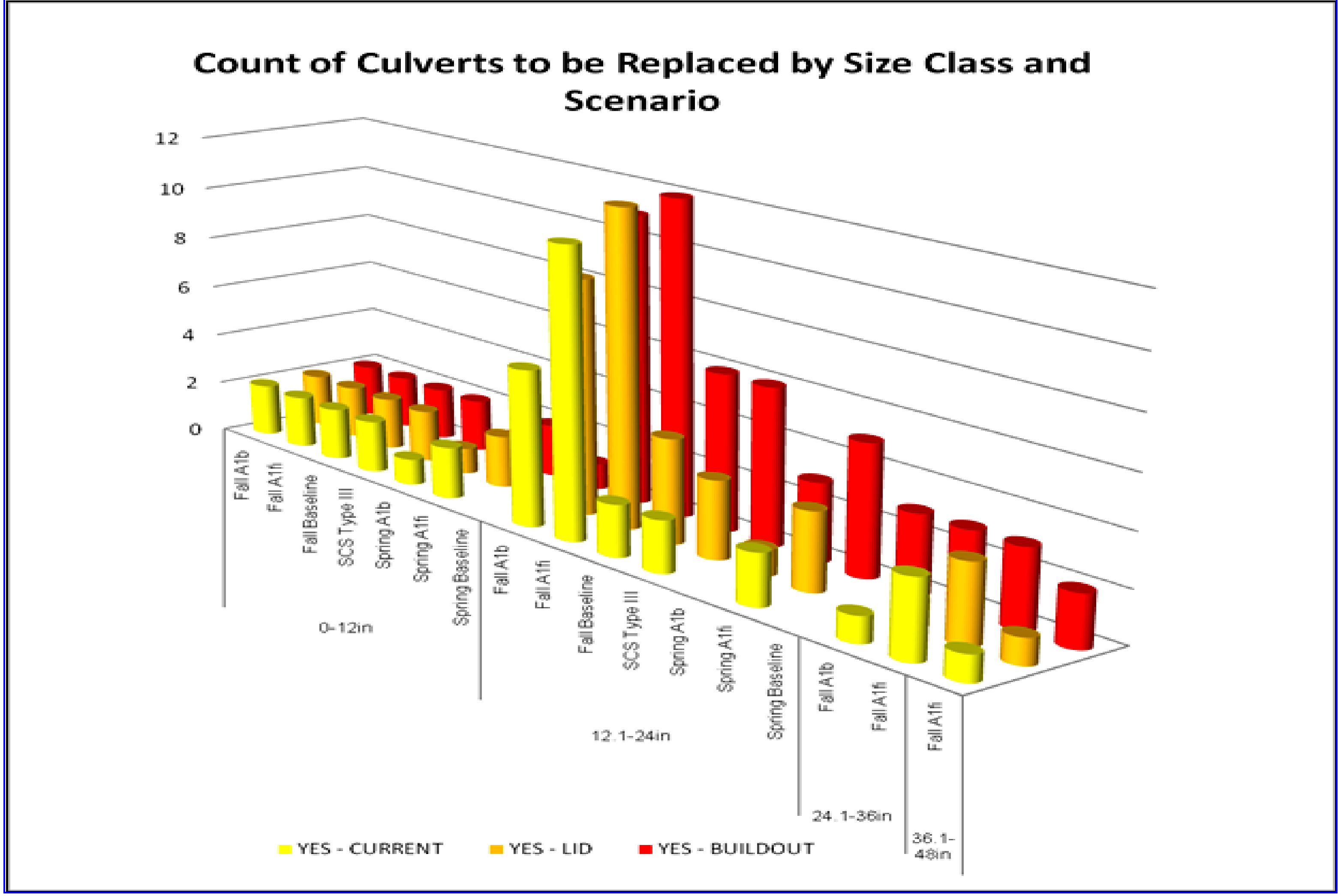
And more extreme rainfall



SYNTECTIC INTERNATIONAL ANTIOCH UNIVERSITY NEW ENGLAND

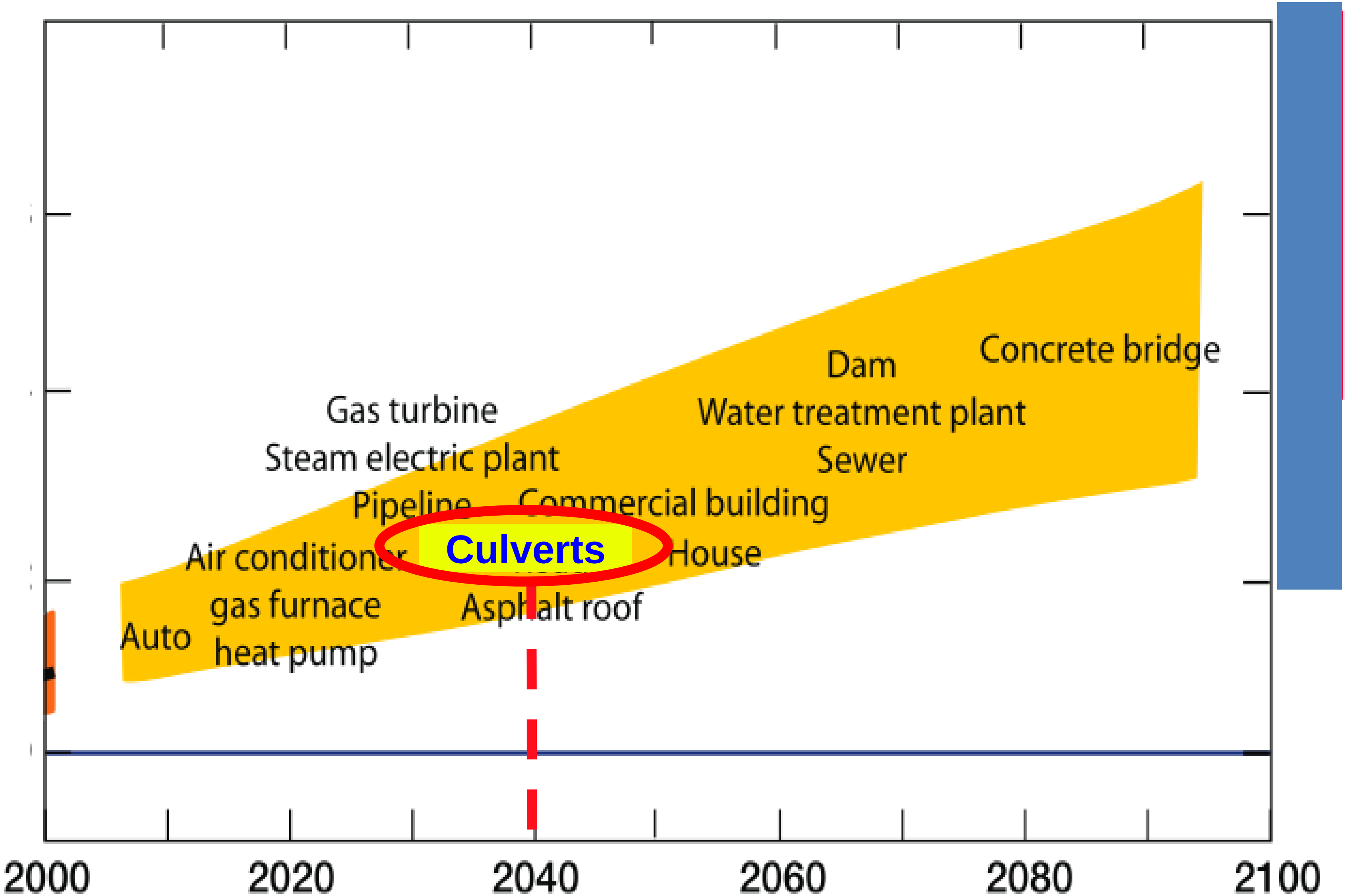
Culvert	stream order	road class
Bear08	1	V
Bear100	2	V
Beau100	1	V
Ches01	1	V
HAME03	1	V
HAME100	1	V
Hame04	1	V
Litt100	1	IV
Litt101	1	IV
LITT102	1	V
Litt104	1	private
Long02	1	V
Oyst01	2	V
Oyst101	2	V
Oyst102	2	V
OYST103	1	V
Unkn10	1	VI
Unkn21	2	V
Unkn22	1	II
Unkn26	1	I
Unkn29	1	private
Unkn32	1	II
Unkn34	1	V
Unkn41	1	V
Unkn42	1	V

Culverts undersized tended to be higher in the watershed and under roads that were not major thoroughfares.



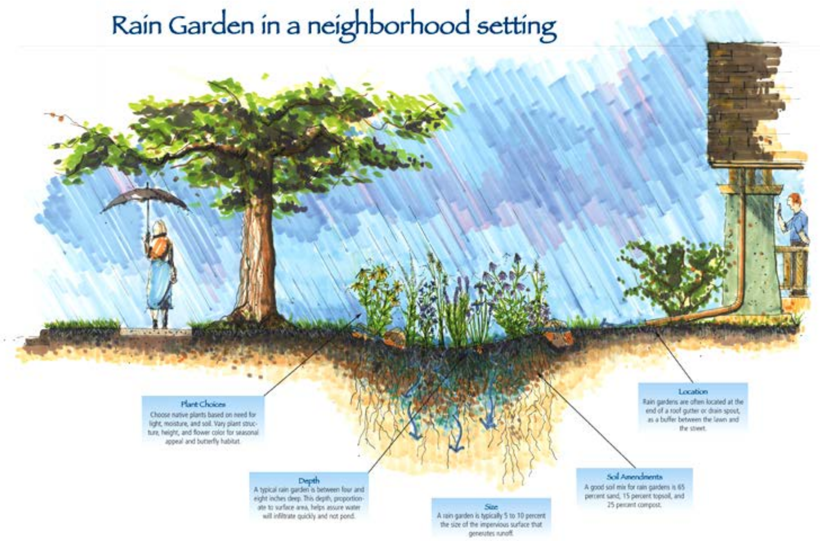
Culverts undersized tended to be in the 12 to 24 inch range

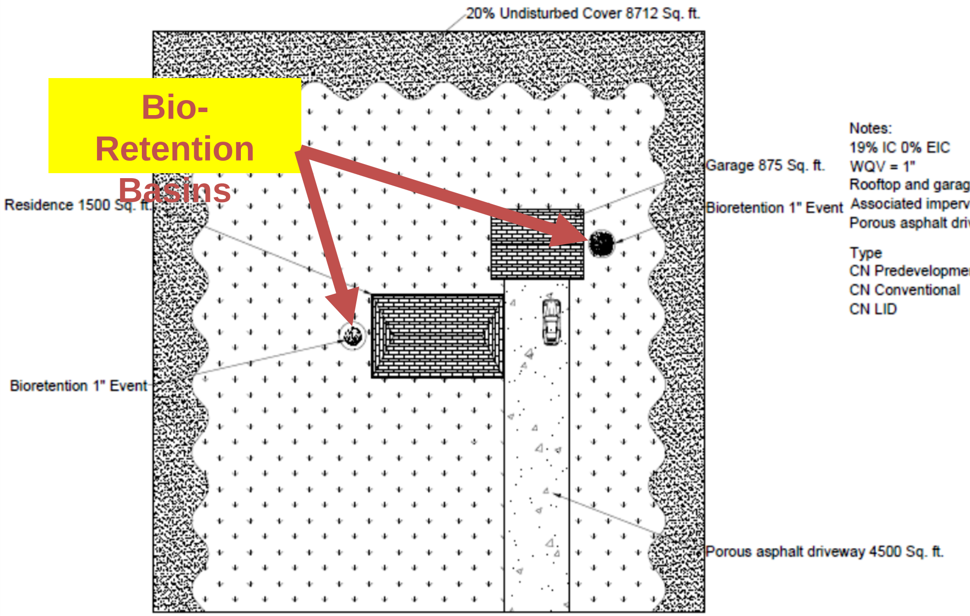
Infrastructure Replacement Time Horizon



Marginal upgrade cost, population growth & more extreme

Precipitation	Marginal Cost
Recent ('71-'00)	67,959
Heavy	100,029
Heavier	185,643
Very Heavy	428,007





Notes:
19% IC 0% EIC
WQV = 1"
Rooftop and garage bioretention
Associated impervious surface biorentention
Porous asphalt driveway

Type	A	B	C	D
CN Predevelopment	38	55	70	77
CN Conventional	51	68	79	84
CN LID	43	62	74	80

Rev.	Date	Notes
1	02/10/11	

Client

Project Partner

Drawn By: RJD

Check By: RR

Sheet Number

1 of 1

1 Acre Lot

Project

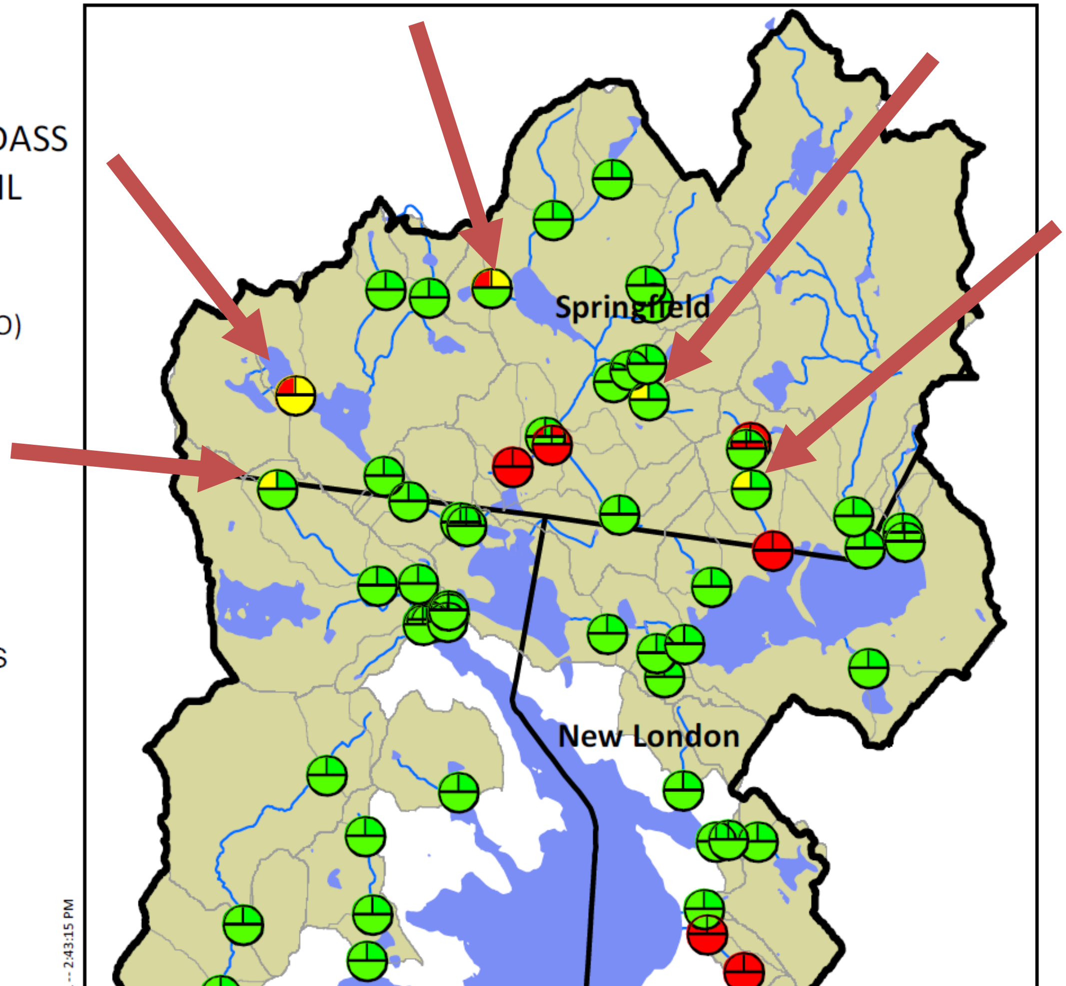
UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

COMPARISON OF LANDUSE RESULTS

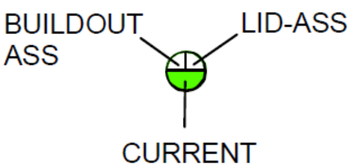
LU: CUR/BLDASS/LIDASS
PRECIP: BASELINE ML
AMC: TYPE II

REPLACE (YES, TRANS, or NO)

- YES
- TRANS
- NO



Result Position



SYNTECTIC INTERNATIONAL

ANTIOCH UNIVERSITY NEW ENGLAND

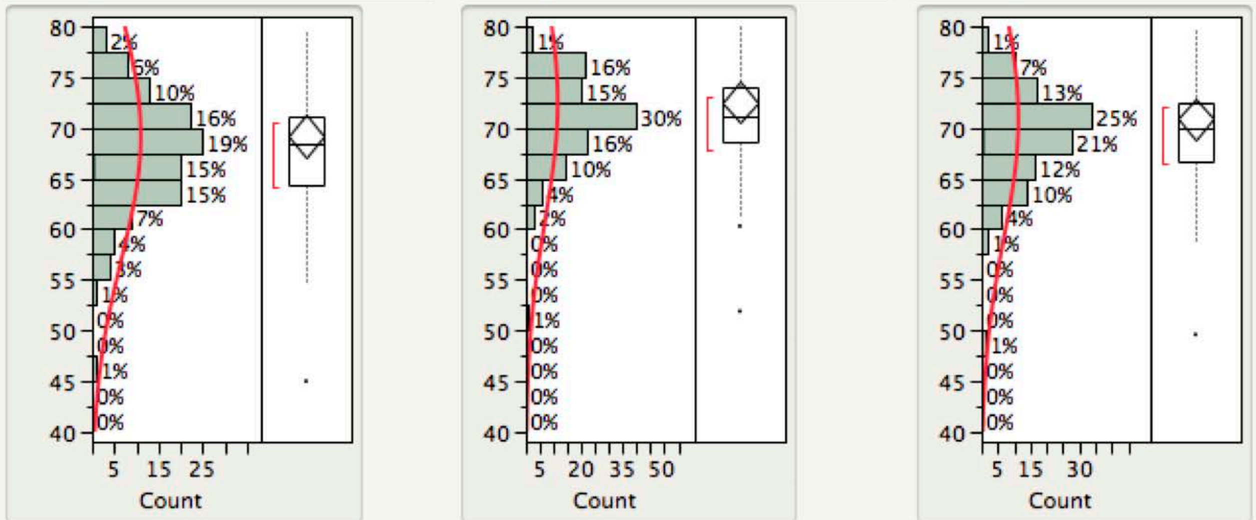
NOAA

Climate Techniques

Average basin run-off due to build out scenario was decreased by an 66%.

Distributions

CN, Landuse = Current	CN, Landuse = BldASS	CN, Landuse = LID-BldASS



Normal(69.1955,12.1387)		Normal(72.5291,11.6087)		Normal(70.891,11.8007)	
Moments		**Moments**		**Moments**	
Mean	69.195522	Mean	72.529104	Mean	70.891045
Std Dev	12.138665	Std Dev	11.608655	Std Dev	11.800723
Std Err Mean	1.048621	Std Err Mean	1.0028351	Std Err Mean	1.0194272
Upper 95% Mean	71.269654	Upper 95% Mean	74.512673	Upper 95% Mean	72.907432
Lower 95% Mean	67.121391	Lower 95% Mean	70.545536	Lower 95% Mean	68.874657
N	134	N	134	N	134
Sum Wgt	134	Sum Wgt	134	Sum Wgt	134
Sum	9272.2	Sum	9718.9	Sum	9499.4
Variance	147.3472	Variance	134.76088	Variance	139.25706
Skewness	4.5975443	Skewness	5.1810391	Skewness	4.9897008
Kurtosis	26.069068	Kurtosis	30.50944	Kurtosis	28.91335
CV	17.542559	CV	16.005513	CV	16.646282
N Missing	0	N Missing	0	N Missing	0

For specific culvert basins

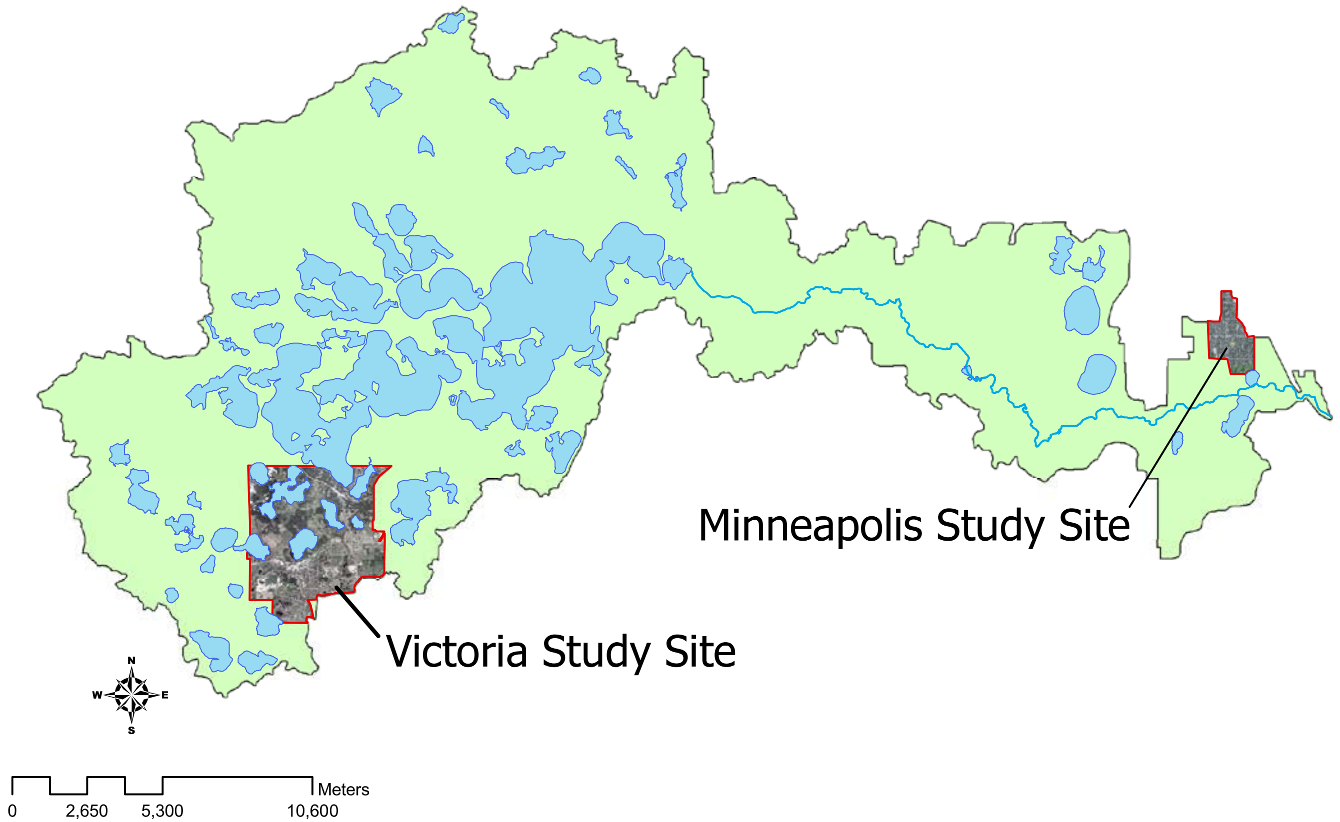
Build-out with LID

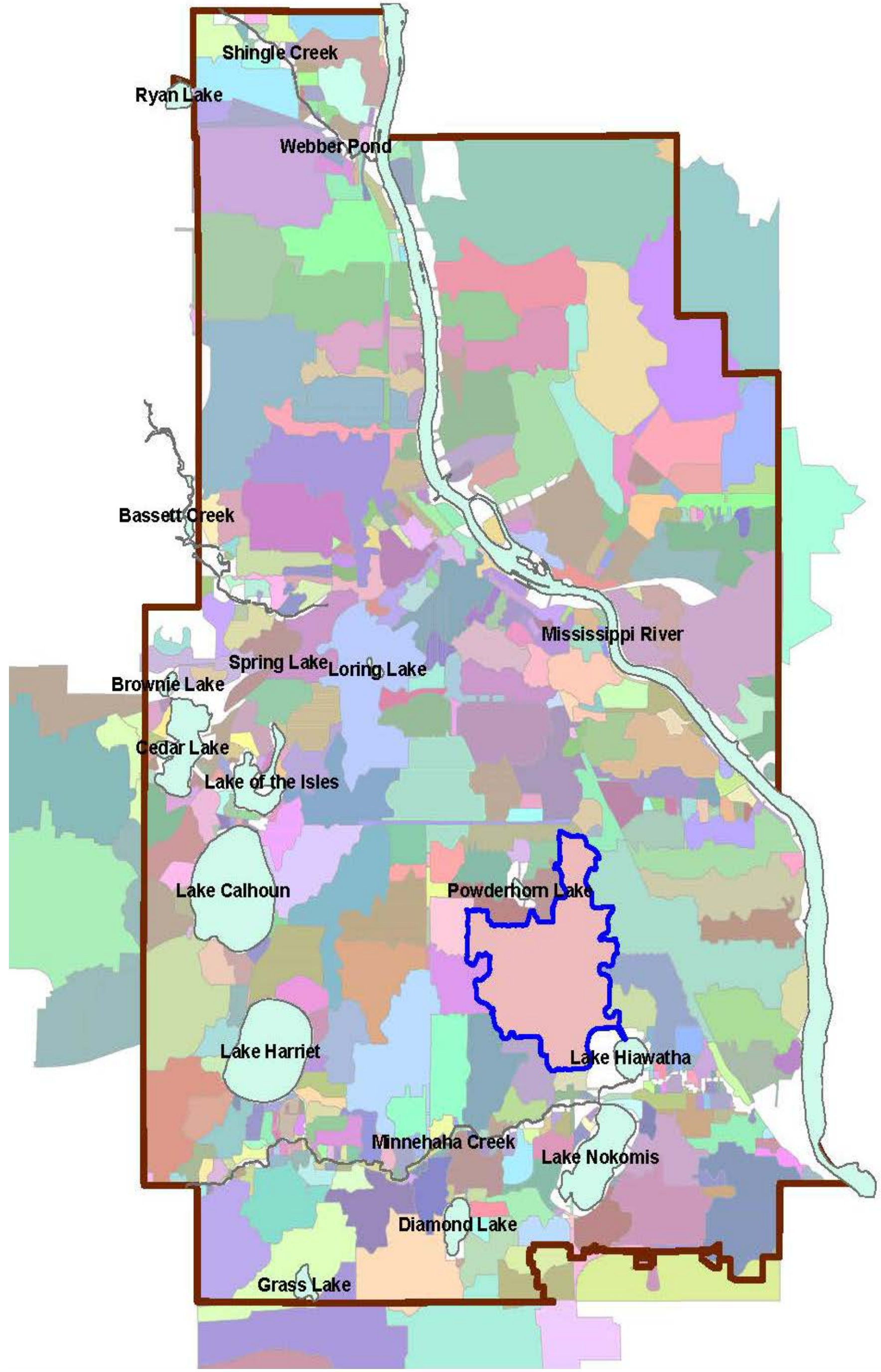
<u>reduced the marginal cost</u> of upgrading by as much as 25%

Impact of LID on total upgrade cost			
	Buildout	LID	Δ%
Recent ('71-'00)	1,311,067	1,303,531	0.6%
Heavy	1,327,136	1,293,605	2.6%
Heavier	1,412,750	1,382,501	2.2%
Very Heavy	1,655,115	1,573,679	5.2%

Number of undersized components			
	Buildout	LID	Δ%
Recent ('71-'00)	19	16	19%
Heavy	19	17	12%
Heavier	28	24	17%
Very Heavy	41	39	5%

Minnehaha Creek Watershed




Shingle Creek
Ryan Lake
Webber Pond
Bassett Creek
Mississippi River
Spring Lake
Loring Lake
Brownie Lake
Cedar Lake
Lake of the Isles
Lake Calhoun
Powderhorn Lake
Lake Harriet
Lake Hiawatha
Minnehaha Creek
Lake Nokomis
Diamond Lake
Grass Lake

Design Rainfall Amounts (inches)	Percentage Chance of Annual Rainfall	Return Period (year storm)
2.50	**100%**	**1**
2.80	40%	2.5
3.60	20%	5
3.80	13.33%	7.5
4.10	10%	10
4.80	4%	25
5.40	2%	50
5.70	1.33 %	75
6.00	1%	100

Return Period : Current and Future

Return period (years)	Recent climate	mid-21st cent. Optimistic	mid-21st cent. Moderate	mid-21st cent. Pessimistic
2.5	2.5	2.84	3.3	6.86
5	3.17	3.47	4.11	8.4
7.5	3.57	3.88	4.66	9.39
10	3.86	4.19 9%	5.1 32%	10.13 162%
25	4.84	5.28	6.74	12.75
50	5.67	6.22	8.31	15.03
75	6.2	6.82	9.39	16.5
100	6.59	7.27	10.23	17.59

3.18-in Storm

Pipe Capacity
Adequate
Undersized

Existing Pipe System Adequacy, Pipe and Street Storage Capacity 3.93 in

No surcharge

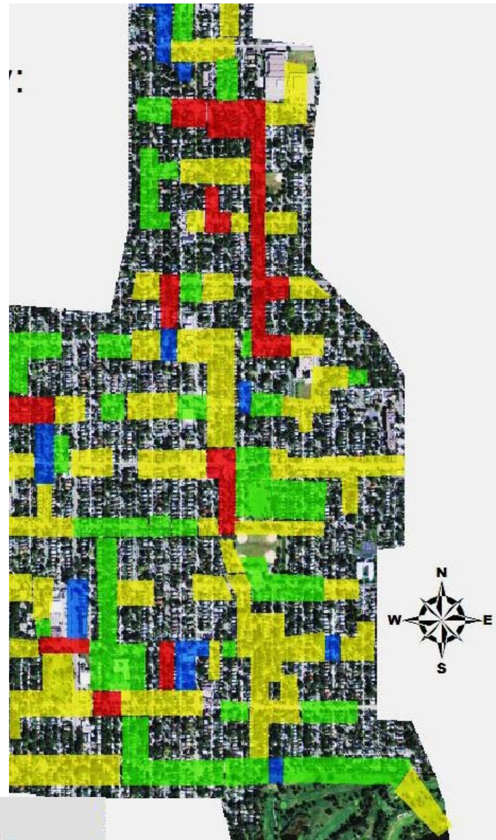
Surcharged, No surface flooding

Surcharged, Streets contain surface flooding

Surcharged, Over-curb flooding

3.9 “

6.6 “

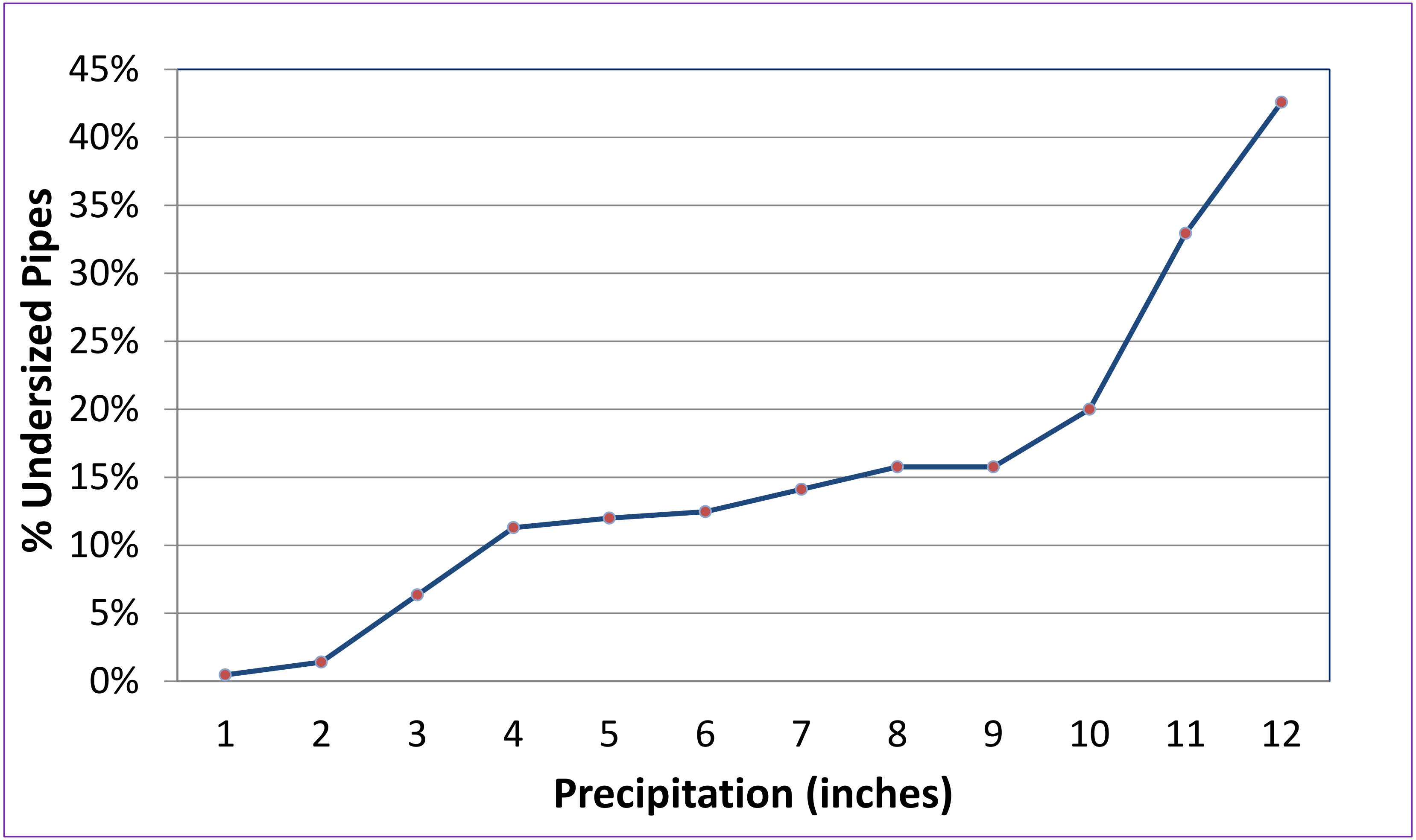


10.1 “

Pipe Adequacy and Surface Flooding

- No surcharge
- Surcharged, No surface flooding
- Surcharged, Streets contain surface flooding
- Surcharged, Over-curb flooding

Hiawatha : % Of Undersized Pipes …with Increasing Rainfall

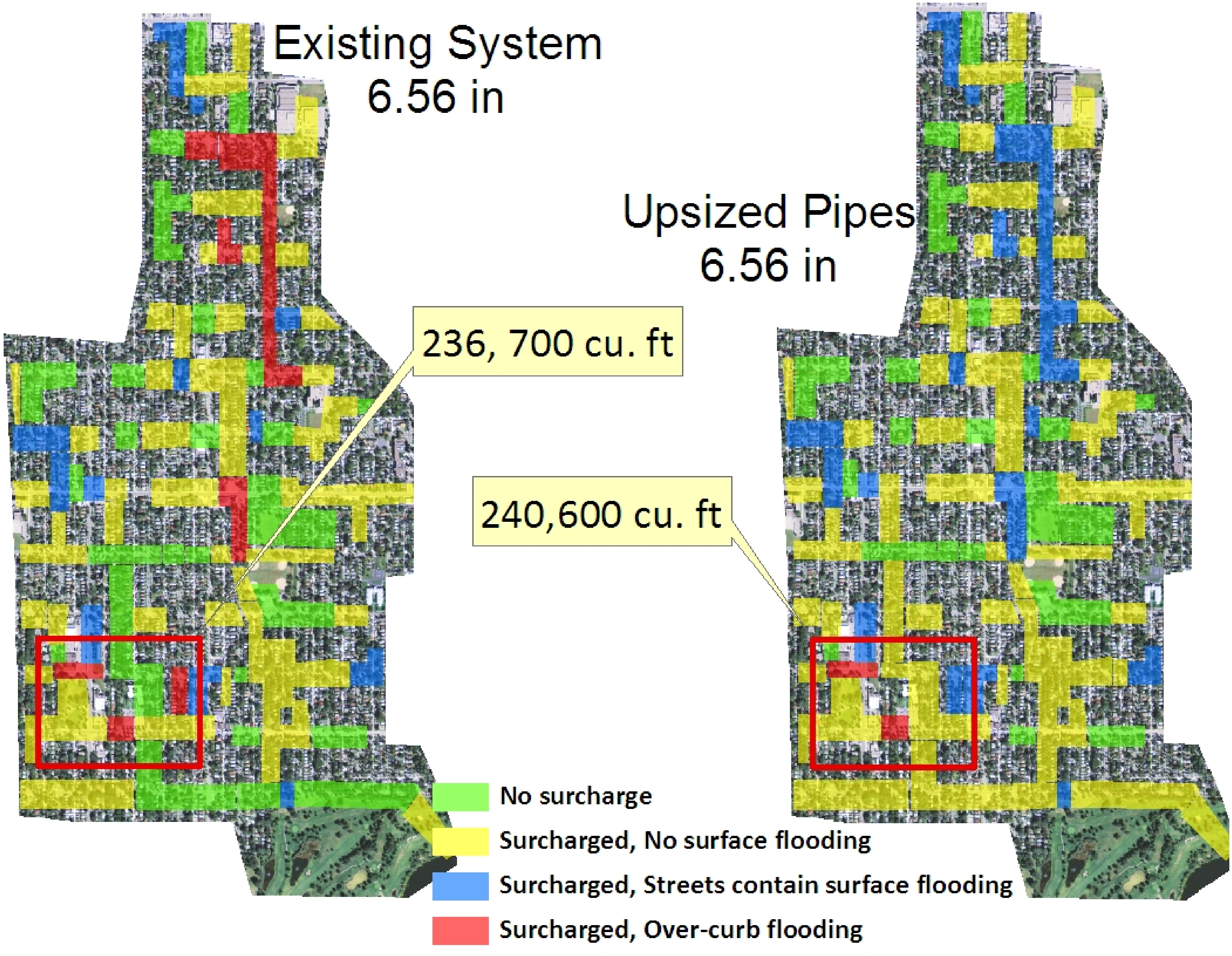


Hiawatha :
System Flood Volumes

Precip. Scenario (in)	Flood Volume (MG)		
	Total	Street Storage	Over-curb
3.93	2.46	1.61	0.86
4.15	2.92	1.80	1.12
4.77	3.95	2.30	1.66
5.66	5.82	3.07	2.75
6.56	10.05	3.70	6.34
8.07	20.02	5.41	14.61
10.1	40.05	5.94	34.11

Hiawatha : (Preliminary) Cost Estimates for Up-sizing Pipes

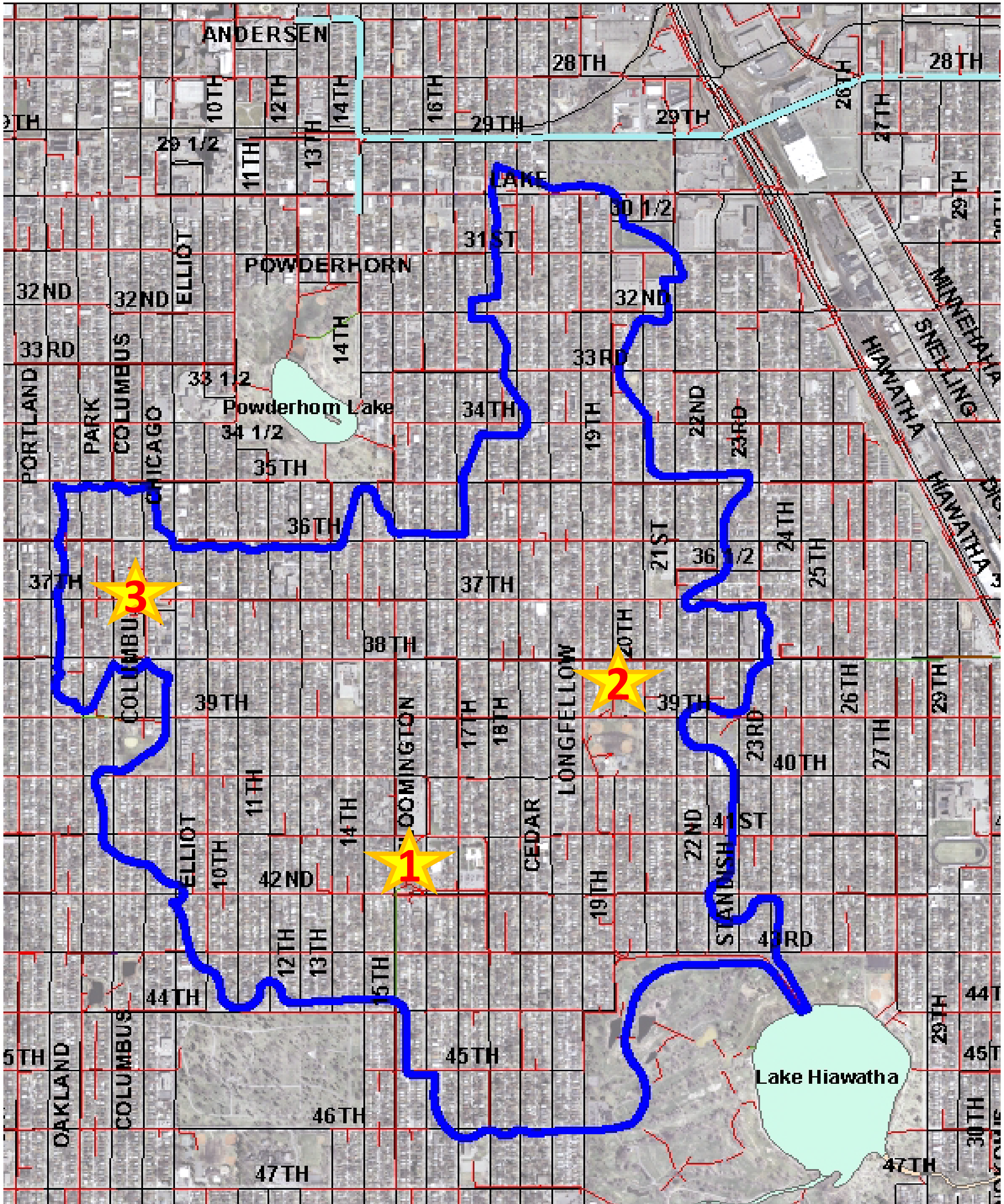
Precip depth (inches)	Qp (cfs / ac)	pipe replacement (feet)	low cost	high cost
4.15	2.04	3439	$ 3,994,155	$ 9,083,822
4.77	2.44	5740	$ 6,666,603	$ 15,161,715
5.66	3.02	12272	$ 14,253,058	$ 32,415,430
6.56	3.63	20405	$ 23,698,961	$ 53,898,048


Existing System
6.56 in
Upsized Pipes
6.56 in
236, 700 cu. ft
240,600 cu. ft
No surcharge
Surcharged, No surface flooding
Surcharged, Streets contain surface flooding
Surcharged, Over-curb flooding

1

Bancroft Meadows Flood Basin **Built 1989**

(Bloomington and 42nd)

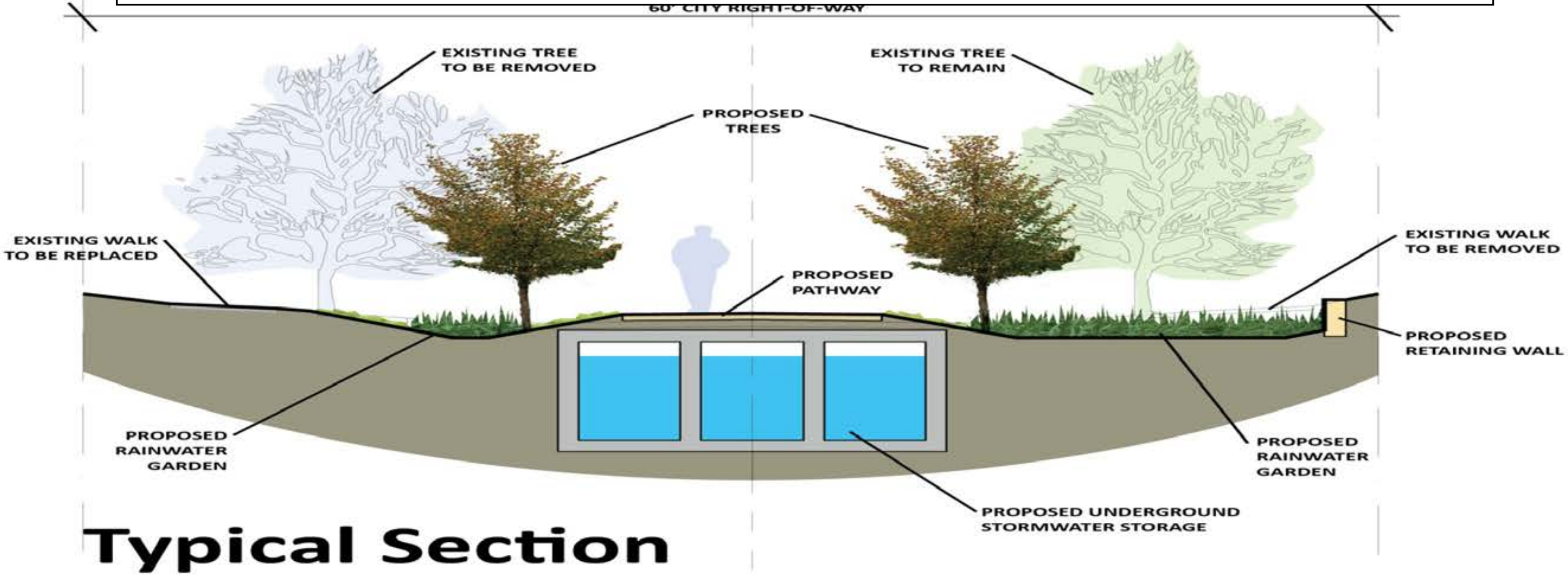

ANDERSEN
28TH
29TH
29 1/2
10TH
11TH
12TH
13TH
14TH
16TH
LAKE
30 1/2
31ST
POWDERHORN
32ND
ELLIOT
33RD
33 1/2
Powderhorn Lake
34 1/2
34TH
PORTLAND
PARK
COLUMBUS
CHICAGO
35TH
19TH
22ND
23RD
36TH
21ST
36 1/2
24TH
25TH
37TH
38TH
20TH
LONGFELLOW
39TH
BLOOMINGTON
17TH
18TH
26TH
27TH
40TH
41ST
CEDAR
STANDISH
42ND
43RD
15TH
44TH
45TH
46TH
47TH
OAKLAND
Lake Hiawatha
MINNEHAHA
SNELLING
HIAWATHA
30TH
1
2
3

Hiawatha :
Dry Basin Cost Estimates for Post-Piping Upgrade Volumes (preliminary)

Precipitation (inches)	Flooding Volumes (Mgal)	Excess Vol. w/ pipe upsizing (Mgal)	Excess Vol. acre-feet	low costs	high costs
6.56	10.05	4.24	13	$124,562	$177,946
8.07	20.02	9.97	31	$293,243	$418,919
10.10	40.05	20.03	61	$589,076	$841,537

The largest box culvert sections are 18 feet wide by 10 feet high

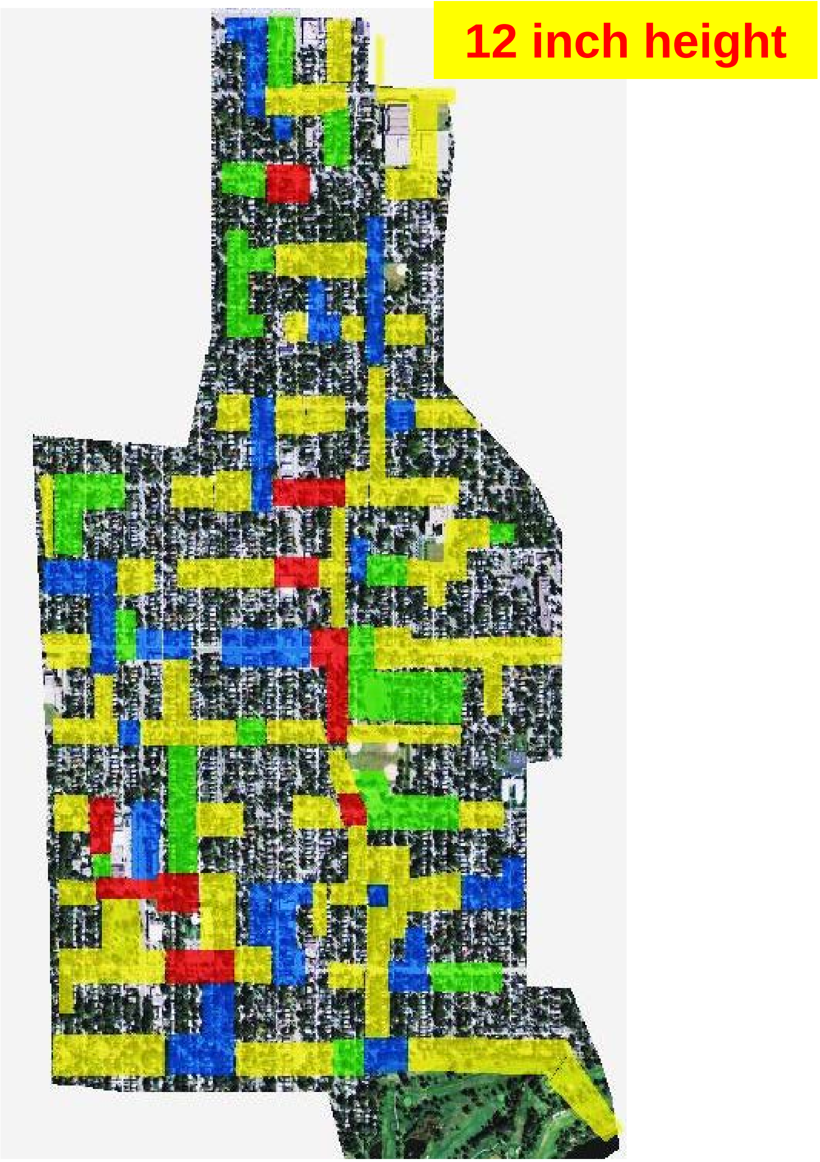
37th Avenue Greenway Flood Project Built 2011

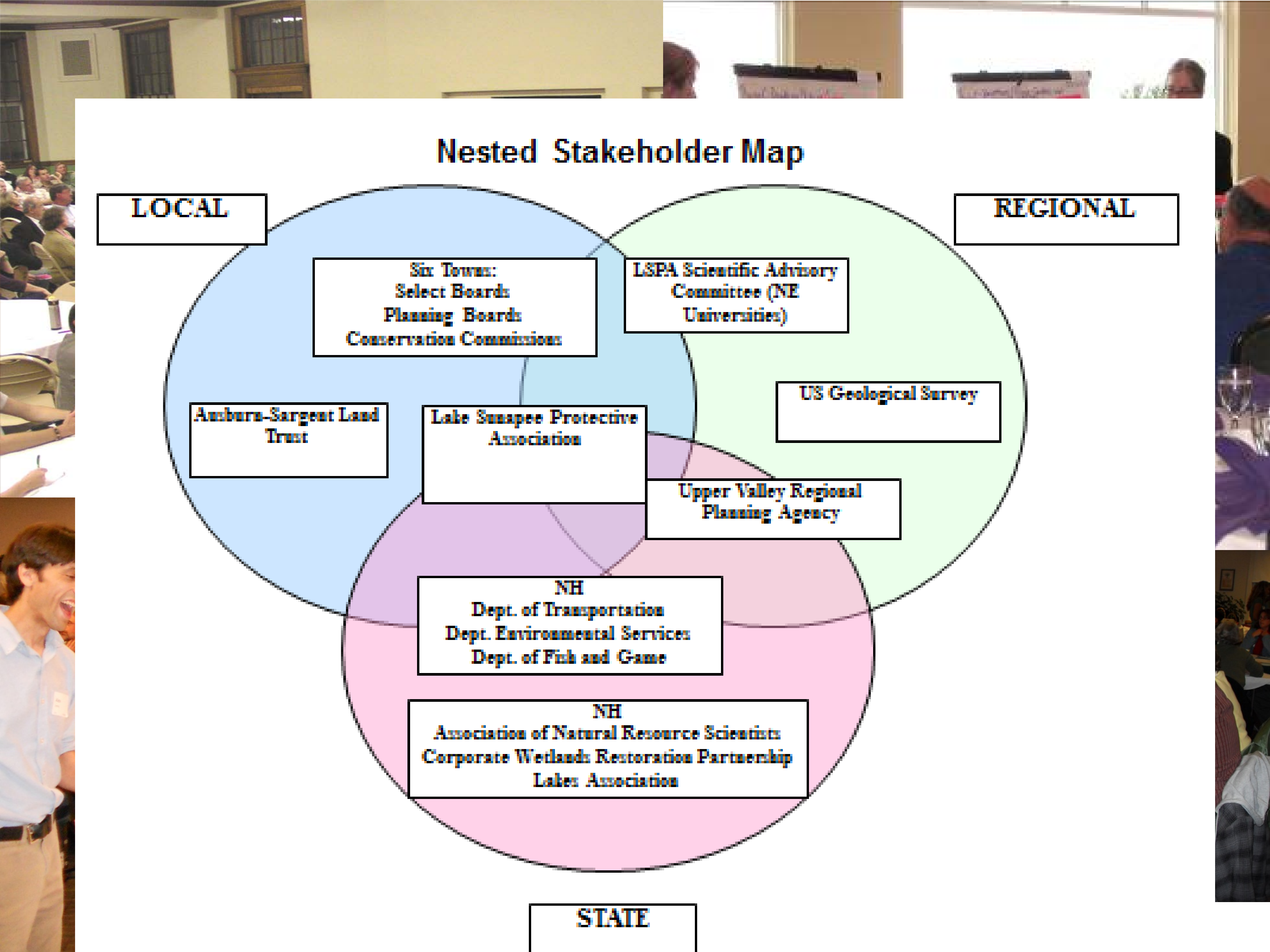


Hiawatha :
Underground Storage Cost Estimates for Post-Piping Upgrade Volumes (preliminary)

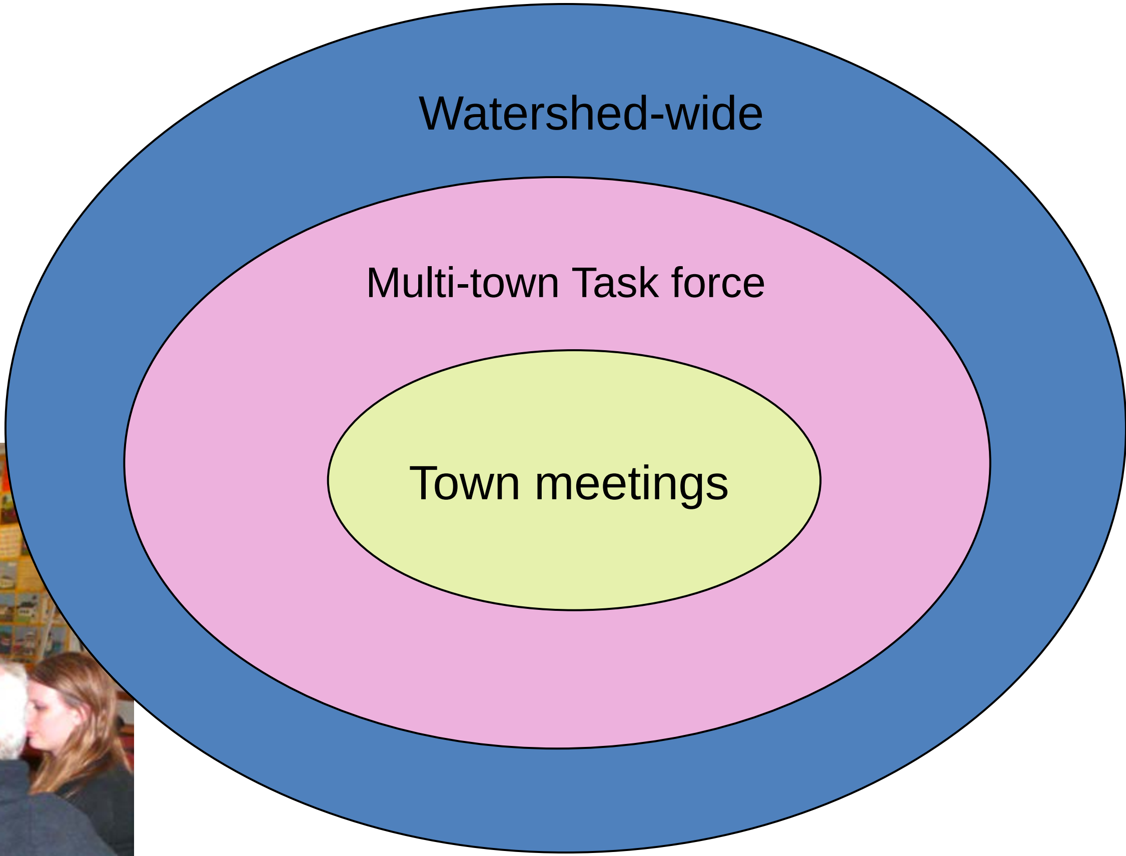
Precipitation	Flooding Volumes (Mgal)	Excess Vol. w/ pipe upsizing (Mgal)	Excess Vol. acre-feet	Estimated Underground Basin Costs	# of projects comparable to 37th ave
6.56	10.1	4.2	13.0	$ 9,833,167	4
8.07	20.0	10.0	30.6	$ 23,149,155	9
10.1	40.1	20.0	61.5	$ 46,502,636	18

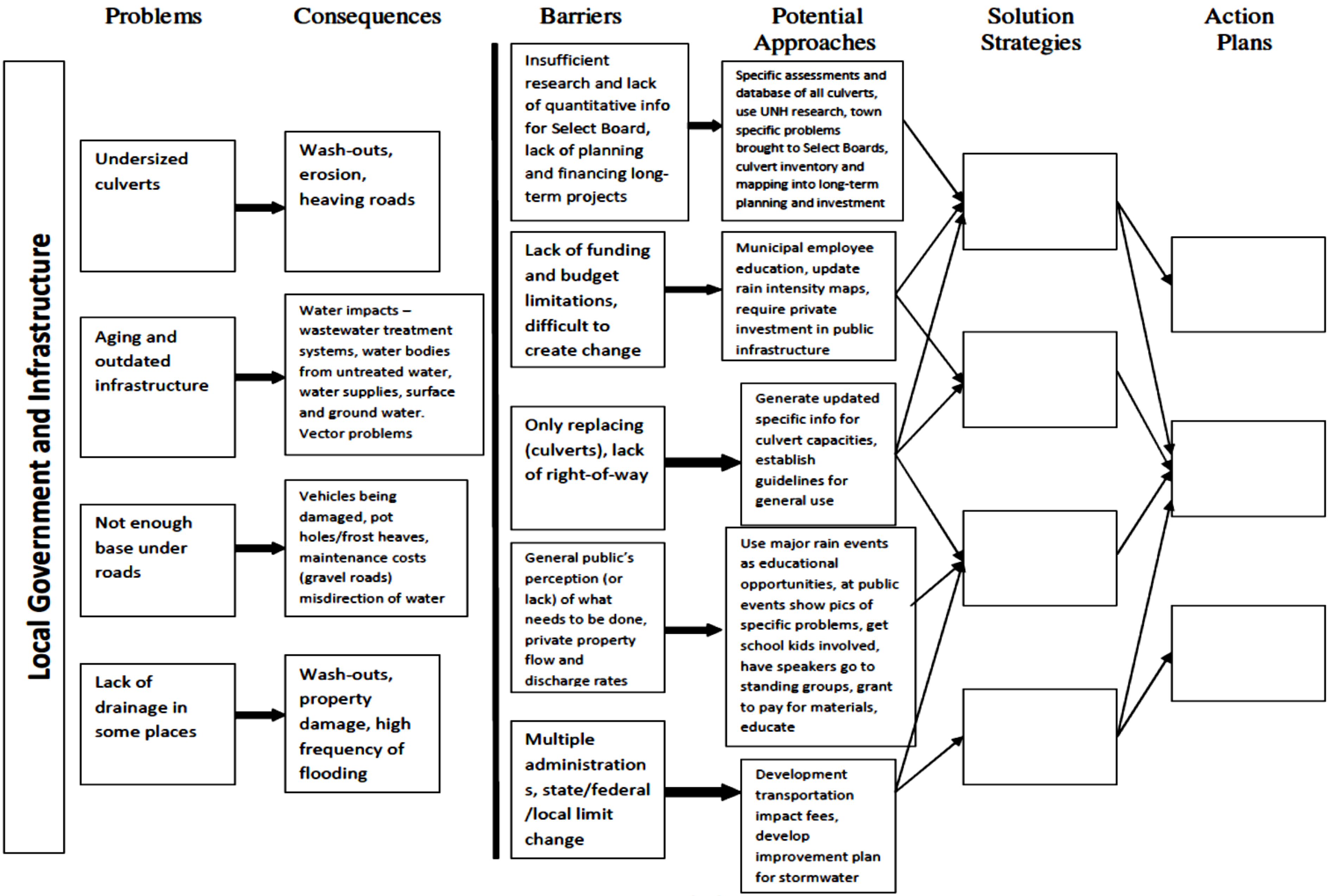
10.1” Rainfall Street Flooding Potential (red)




Nested Stakeholder Map
LOCAL
REGIONAL
STATE
Six Towns:
Select Boards
Planning Boards
Conservation Commissions
LSPA Scientific Advisory Committee (NE Universities)
US Geological Survey
Ausburn-Sargent Land Trust
Lake Sunapee Protective Association
Upper Valley Regional Planning Agency
NH
Dept. of Transportation
Dept. Environmental Services
Dept. of Fish and Game
NH
Association of Natural Resource Scientists
Corporate Wetlands Restoration Partnership
Lakes Association

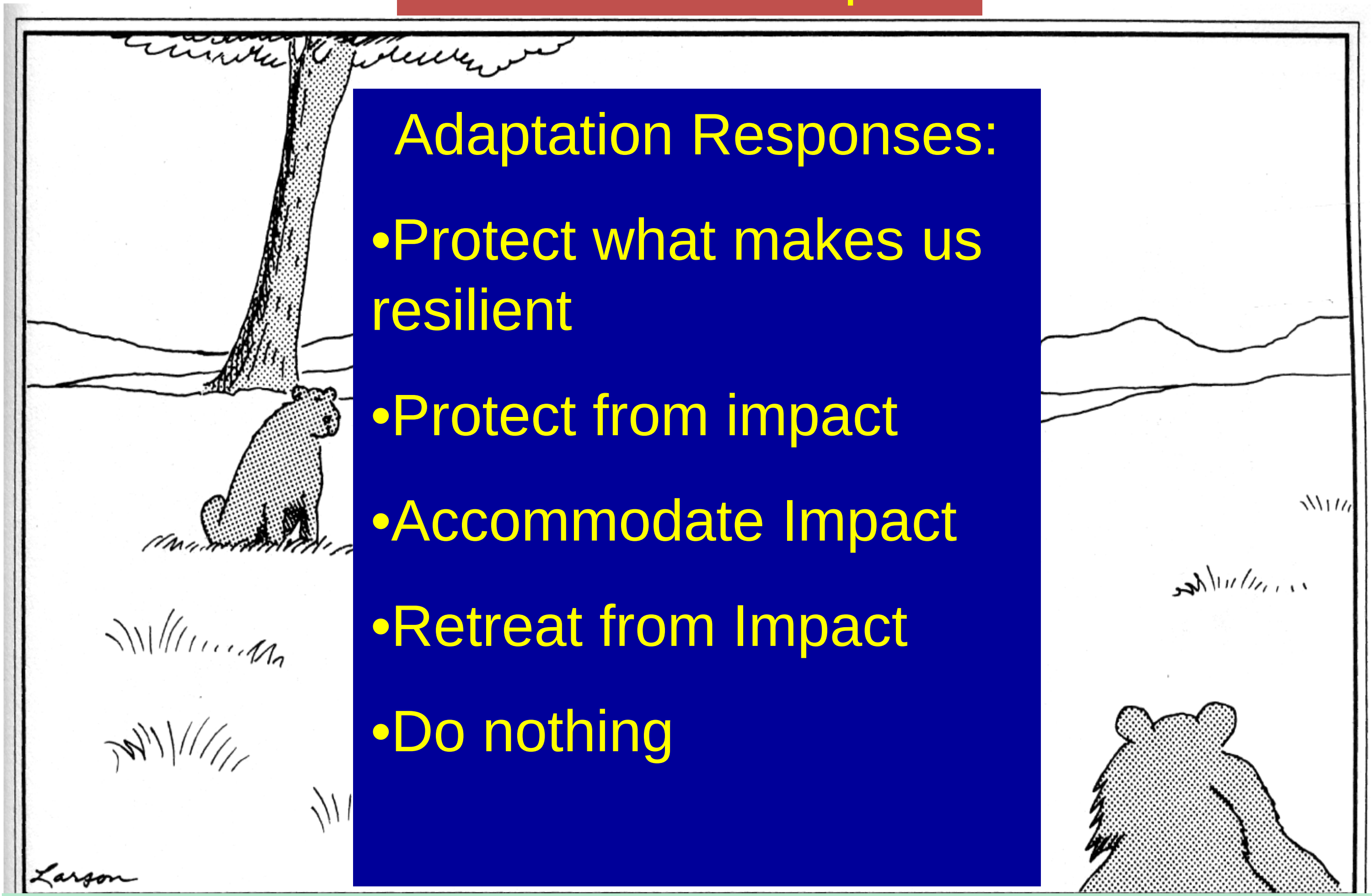
Nested Adaptive Management Approach





Local Government and Infrastructure Task Force Meeting. 4/21/10. 6:30 – 8:15. Lake Sunapee Protection Association Offices

The need to Adapt



Adaptation Responses:

- Protect what makes us resilient
- Protect from impact
- Accommodate Impact
- Retreat from Impact
- Do nothing

"Drive, George, drive! This one's got a coat hanger!"

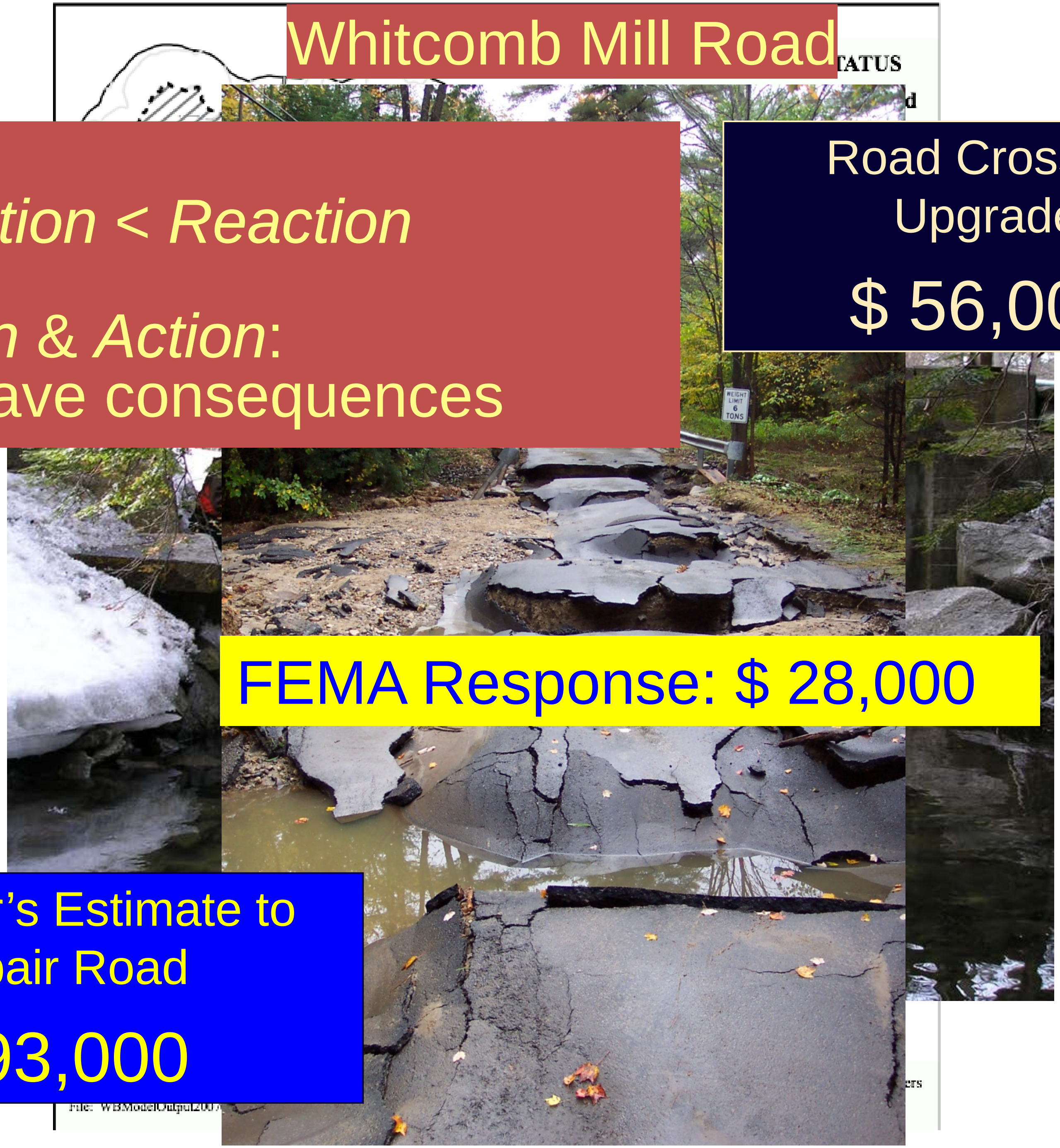
Whitcomb Mill Road

- Cost:
  Pro-action < Reaction

- *Inaction & Action*:
  both have consequences

Road Crossing Upgrade

$ 56,000



FEMA Response: $ 28,000

Engineer's Estimate to Repair Road

$ 93,000